COST
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

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: Smart textiles with integrated PV`s for improving the buildings` energy performance
STSM start and end date: 11/12/2019 to 28/12/2019
Grantee name: Lela Hristovska

PURPOSE OF THE STSM/

The construction industry is pointed as one of the most intensive industries with a share of 50% in resource consumption, 40% energy consumption and 50% waste creation. The largest part of the existing buildings are designed in an unsustainable manner and thus held responsible for nearly 40% of the global energy consumption and approximately 36% of the total carbon dioxide emissions. The concept of sustainability means meeting the basic needs of all people and extending the opportunities for environmental, economic and social advancement. Therefore, the delivery of sustainable buildings is of great importance for the future sustainable development of humanity.

The development of the smart textiles and ICT technologies, offers solutions to improve the buildings` energy performance and sustainability. The integration of smart textiles with photovoltaics` enables decrease of the use of non-renewable energy and mitigate the CO2 emissions from buildings. Therefore, there is an urgent need for an increased application of smart textiles in buildings` facades, especially ones that can improve the buildings thermal performance, enable PV energy production and similar, in order to achieve sustainable buildings. Also, the ICT technology provides means for holistic integration of the smart textiles in order to adapt to the changing climate conditions. Further, the degree of controllability of the smart textiles can contribute towards the satisfaction of the buildings` users and their everyday life by providing user feedback, control, assistance etc. Considering the need of the society for adapting to the changing climate, the smart textiles can meet these demands, as they are light materials to adapt to the desired shape of the buildings` façade and to meet the demands for energy performance and interior comfort. In order to achieve these complex tasks it is necessary to investigate the influence the smart textiles can have onto the buildings` performance.

Therefore, the objective of this STSM is to show that smart textiles with integrated PVs` can significantly contribute towards an improved energy performance of a building and contribute towards its sustainability. The scientific aims and outcomes of the STSM research are: to investigate the application of smart textiles in buildings; to investigate the integration of PV`s with smart textiles and their application; to develop software models of an office building with several different façades made of smart textiles integrated PVs and prepare it for energy performance analysis; to compare the performance of a glazed façade with different geometries of textile facades some of which have integrated PV`s; To contribute towards the creation of a knowledge base for application of smart textiles in the building construction industry and the creation of sustainable buildings.

During the STSM several computer models of façades with smart textiles will be developed and compared regarding their contribution to shading of the interior, energy savings and solar energy production. Hence, the STSM will contribute towards an investigation of the possibilities of application of smart textile with PV`s and their contribution towards the buildings` energy performance. The results of the STSM will show how different design scenarios of an office building façade influences the buildings` performance, compared to a traditionally glazed façade. By conducting such a comparison, relevant data will be gained which will increase the knowledge among the architects and engineers and stimulate a wider application of smart textiles in the buildings` façade design. Also, having in mind that the construction industry is among the largest contributors to the European economy, the future development of smart textiles and possibilities for application in buildings is of utmost importance.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

In order to achieve the objectives and aims of the proposed STSM, different research techniques are used such as: review of state of the art papers regarding smart textiles, PVs` and their integration; computer modeling of several facades made of smart textiles with PVs; software simulation of energy performance of the developed facades with textile and PVs`; aggregation, processing and analysis of the obtained results from the energy performance simulation

In the literature review phase, the most relevant achievements and research papers are investigated and analyzed, especially regarding the different smart properties of textiles, their active and passive features, followed by an investigation on smart textiles application in buildings` facades, smart textiles which can be integrated with PVs` and their potential to contribute towards improved energy performance of buildings and contribute towards its sustainability. Moreover, the potential of smart textiles` is analyzed regarding their application in buildings, such as: possibilities for new forms, regulation of daylight, regulation of sound, energy efficiency, lightness, mobility, adaptability, sustainability etc. Therefore, the incorporation of various functions that the textile may incorporate are noted, such as: sensing, actuating, powering/generating, communicating etc. In that view, the barriers and drivers for the implementation of smart textiles are noted. Further, an examination was made regarding the state-of the art of PV types, PV production and possibilities for integration with various substrates of textiles. Additionally, in order to integrate the smart textiles in the holistic concept of smart homes, the internet and communication technologies are investigated as well as different mechanical devices, sensors etc., which altogether can contribute to the delivery of a high-performing sustainable building.

The research continued with the development of computer models of an office building which was done in the software SketchUp and OpenStudio which has EnergyPlus simulation. Several façade types of smart textiles and PVs` are modeled and simulations are performed regarding their energy performance. The final activities of the STSM included analysis of the results of the energy performance simulations and their comparison showing that smart textiles for solar harvesting have a huge potential for development and application.

The aims and objectives of the proposed STSM research relate to the work of the Working Group 4 - Smart textiles for building and living applications. Hence, I strongly believe that the realization of the proposed STSM research will significantly contribute towards the research objectives of the CONTEXT Action, as stated in the Memorandum of Understanding of the Action especially to the Research Coordination Objectives, such as: RCO5: Introducing and promoting the sustainability concept in the research and development of new textile advanced products in order to adapt the sector to the new competitive and environmental rules and RCO8: Foster the transfer of knowledge among different actors in order to find suitable applications in various multidisciplinary fields e.g. buildings. The findings of the research are planned to be published in a relevant conference and journal paper for which the Action will be greatly acknowledged.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The investigation of the state-of-the-art achievements in smart textiles regarding their application in buildings` facades shows they are a very promising material for improving the buildings` performance and sustainability. Considering they have the ability to sense and respond to changes in their environment they can efficiently adapt to to the climate changes and the unpredictable weather, providing comfort indoors. In that regard they can significantly further develop the domain of adaptive facades. There are numerous functionalizes of the smart textiles such as: energy generation, self-cleaning potential etc., among which solar harvesting is of considerable interest for the delivery of sustainable buildings.

Various production methods are investigated. Widespread method for production of solar textile fabric is by attaching a thin film of solar plastic to the fabric by sewing, welding or laminating, with a special care not to damage the film, or by uneven stretching and compression. Several studies show PV fiber production by using vacuum thermal evaporation of thin concentric organic PV films onto polyimide-coated silica fibers (which can be adapted to textile fibers). An advantage of rendering fibers PV is that fabric made from them is inherently PV however multiple drawbacks are evidented. A desirable but not developed method is noted, based on a direct deposition of solar cells onto textile fabrics. Regarding deposition of inorganic solar cells, the thermal properties of the fabric are crucial. The organic PV`s can show unstable properties in the presence of oxygen or water vapor. The roll-to-roll process of integration of fabric and PV by lamination of awnings has been successfully developed and tested. Large-scale production has been used for solar cells on a plastic web or metal strip, usually by roll-to-roll coating. Printing processes have been demonstrated for fabricating flexible dye- sensitised solar cells (DSSC), which are now commercially available (e.g. Solaronix and G24i). Functionalization of the surface of fabrics by novel low temperature materials deposited by standard printing processes promises as a cost-effective method. Other PV cells` production is based on liquid coating, such as dye-sensitized solar cells (DSSCs) based on TiO_2, with efficiencies up to 10% but operate in diffuse sunlight opposed to most crystalline cells. DSSCs are made by processes used in the textile industry with efficiencies of 15%. The PV cells based on amorphous silicon are four times less efficient in terms of electrical energy produced per surface unit compared to monocrystalline or polycrystalline silicon, however currently they are the only possible solution for the integration to textile structures.

Several advanced structure designs are noted for the three dimensional photovoltaic fibers wearable solar energy harvesting and conversion, such as: Single fiber, Double fiber structure (two functional fibers with active materials), Multi-fiber structure, Optical fiber structure, Woven structure, Concentrating structure. A 4D printing enhances the attributes of 3D printing and adds a fourth `dimension`, a certain attribute to provide shape, property or functionality evolution over “time”.

The adequateness of a certain textile as a substrate depends on its chemical nature and physical morphology of the fibers, its method of fabrication, its ability to withstand prolonged UV, the required temperatures to for PV films depositing etc. For PVs`, such as crystalline silicon, CIGS and CdTe cells, suitable textiles with high thermal stability are: glass, polybenzimidazole, polyimide fibers and similar, however they are non-economically feasible. At lower temperatures (200°C), mixtures of nanocrystalline and amorphous silicon cells can be deposited. Polyethylene terephthalate (PET) fibers are noted as potential substrates (melting at 260–265 °C) and are UV stable. Further during the STSM the development of the 3D model of three case-studies of an office space was done in SketchUp. The case-study` properties and materials are modeled in Open Studio, which is a plugin for SketchUp based on the EnergyPlus engine, and in which the energy performance modeling and simulation was performed. It has to be accented that modeling transient features of the materials is a task limited by the available software tools and in that regard there is a substantial need for software improvement.

The solar smart PV textiles (SSPVT) are modeled in three positions, such as: 0º, 42º and 90º relative to the horizontal plane, named SSPVT1, SSPVT2 and SSPVT3 respectively. There are several significant findings obtained from the simulation results which are intended to be published in a relevant journal/conference paper.

FUTURE COLLABORATIONS (if applicable)

(max.500 words)

The conducting of this STSM research had objectives to complete while the duration of the research stay, but also objective to initiate possibilities for future collaboration with the Host and Hosts` institution. In that regard, we have layed out draft activities to deepen the research on smart textiles` application in buildings construction elements, especially in facades, as well as partition walls. Key questions for further advancements of smart solar textiles are improved energy conversion efficiency and decrease of production costs.

The aspects which can be further investigated are smart textiles integration with actuators and sensors for further development of adaptive facades. Also, smart textiles with thermal storage capacities and low thermal conductance and as insulators should be more investigated. Materials with such performance can strongly contribute to the adaptation of the indoor comfort in regard to the given climatic context surrounding the building, can provide comfortable indoor environment and significantly contribute to the creation of sustainable buildings. Also, it is necessary to perform LCA analysis in order to compare and justify the smart textiles production and their benefits.