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SKin Healthcare by Innovative NanoCAPsuleS

Project Number: 685909

Deliverable D19

D3.2 Textile structures for skin comfort containing stable nanocapsules

Responsible Partner	Devan Micropolis
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Abstract	Different textile structures containing nanoencapsulated phase-change materials were prepared. These textile structures were fully characterised, and their thermal comfort was evaluated both *in-vivo* and *in-vitro*. The results revealed that the incorporation of phase-change materials inside sustainable and bio-based stable nanocapsules provided enhanced thermal comfort properties to the textile structures used as first layer garments.
File Name	SKHINCAPS_Deliverable D3.2 Textile structures for skin comfort containing stable nanocapsules

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INTRODUCTION

Nowadays, the increased awareness of consumers towards healthy and sustainable lifestyle habits is leading to the continuous seek for new technologies suitable for diverse industry sectors, that could satisfy and fulfil people's needs. In this context, nanotechnology is playing a crucial role in the creation of added value daily products, mainly because of the great properties achieved at nanoscale.

Skin Healthcare by Innovative NanoCAPsuleS project aimed to develop customised products (cosmetics and textiles) for skin care using an innovative, cost-effective, safe and sustainable in situ self-assembly nanoencapsulation technology, based on biocompatible and biodegradable polymers and natural active ingredients. These nanocapsules/nanocarriers are stimuli-responsive, safe, controllable and have different release mechanisms for the active ingredients, to achieve distinct properties: thermal comfort, anti-ageing and antimicrobial.

In the case of thermal comfort, no-release nanocapsules (NCs) containing Phase Change Materials (PCM) were developed. These are materials with the property of absorbing and releasing large amount of latent heat energy through phase transformation (Figure 1). The most common PCM is ice, however its use is limited due to fixed melting temperature. On the other hand, on advanced PCM (manufactured using paraffin waxes, fatty acids, and salt hydrates among others), the melting temperature can be modified using appropriate performance-enhancing reagents.

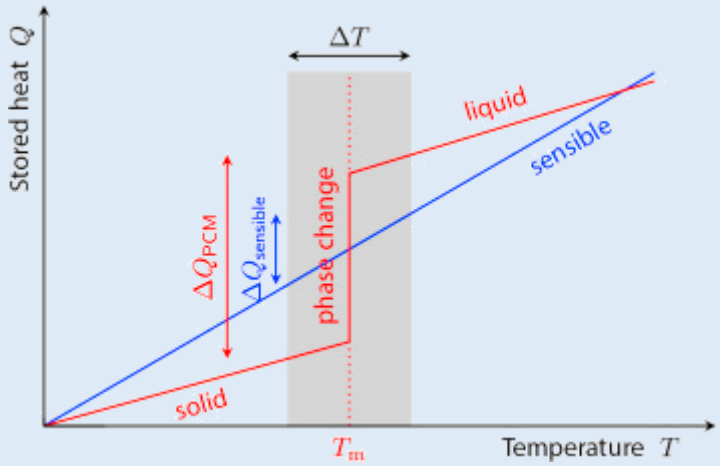

Figure 1. PCM temperature transitions in form of stored heat for thermal management [1]

SKIN THERMAL COMFORT TEXTILES

No-release nanocapsules containing phase change materials were developed for incorporation on functional first layer textiles, to improve skin thermal comfort (Figure 2).

Figure 2. Skin thermal comfort demonstrators (sweater and mini scarf).

[1] M.C Browne et al, Phase change materials for photovoltaic thermal management, Renewable and Sustainable Energy Reviews. Volume 47, July 2015, Pages 762-782. https://doi.org/10.1016/j.rser.2015.03.050.

These textiles have a temperature transition gradient which allows the regulation of the body temperature in different weather conditions, working as a thermal barrier to skin thermal variations: in hot weather conditions, the functional garments keep the body temperature fresher for longer times and in cold weather conditions the effect is the opposite, so that the user feels more comfortable due to the textiles resilience to environmental temperature changes (Figure 3).

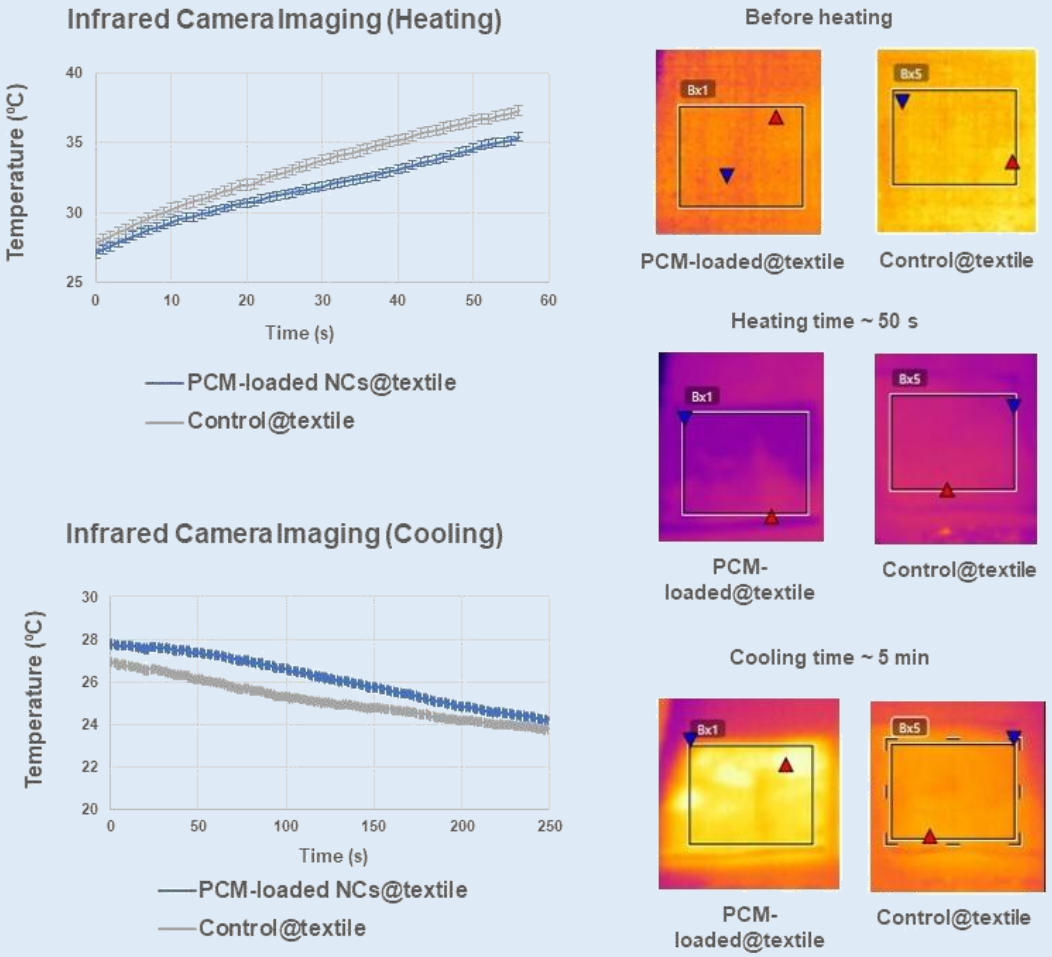

Figure 3. Infrared Camera Imaging results.

This effect will be felt even after several washing cycles, as confirmed by the following results (Figure 4 and Figure 5):

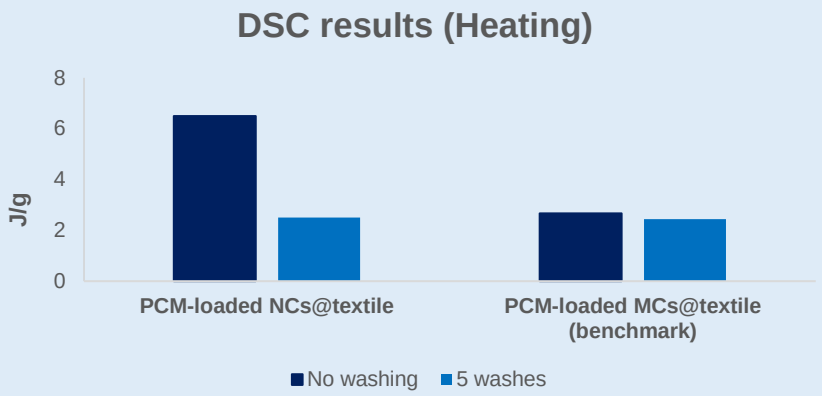

Figure 4. DSC results (heating) for the treated textiles with PCM-loaded NCs and with PCM-loaded MCs (benchmark), before and after 5 washing cycles.

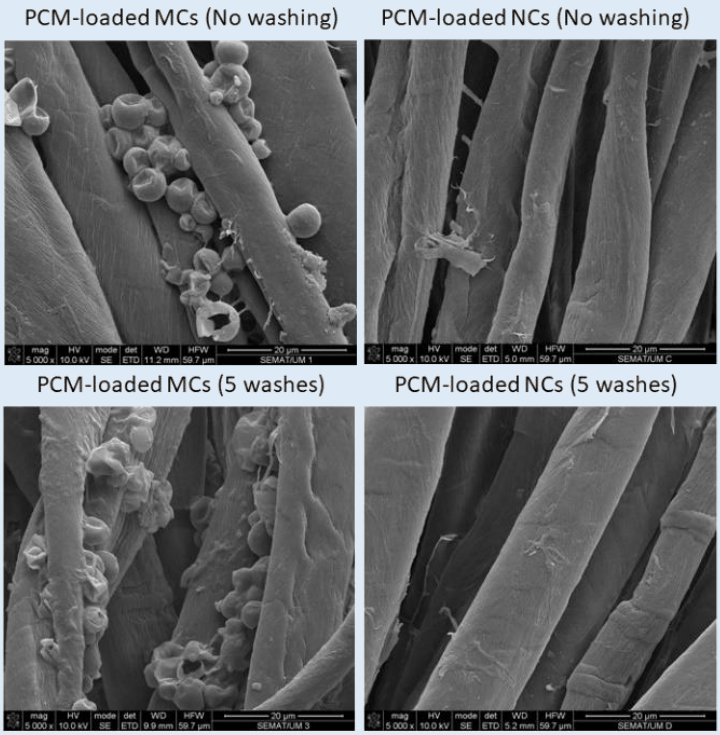

Figure 5. SEM micrographs (5 000x) of the treated textiles with PCM-loaded MCs and PCM-loaded NCs, before and after 5 washing cycles.

The evaluation of the efficacy of the demonstrators was performed *in-vivo* and *in-vitro* in real usage scenarios (Figure 6). The *in-vivo* validation was assessed with a group of healthy volunteers that evaluated the SKHINCAPS' t-shirts in terms of thermal comfort sensation at different environmental conditions: 15 °C and 35 °C. At the end of the test, the volunteers filled a questionnaire, allowing a comparison between the t-shirts functionalized with SKHINCAPS' nanocapsules, a control and the benchmark product. Photographs with an infrared camera were also taken to monitor the temperature of the volunteers before and after the test. The *in-vitro* test was performed with a thermal manikin, in a climate chamber at 15 °C. The different t-shirts were tested for 5 minutes and the test was monitored with an infrared camera.

After analysing the results, it was possible to clearly distinguish the functionalized t-shirts (SKHINCAPS and benchmark) from the control t-shirt, confirming that the treated textiles can work as a thermal barrier.

Additionally, corneometry studies were performed by placing in contact these textiles with the skin of healthy volunteers and it was verified that the textiles containing PCM loaded nanocapsules are harmless to the users, since no side effect was observed for the skin properties – erythema and transepidermal water loss (Figure 6).

Figure 6. *In-vivo* and *in-vitro* evaluations of the performance (above) and the safety (below) of skin thermal comfort demonstrators.

MARKETING POINT OF VIEW

Region-wise, Europe is leading the advanced PCM market. Growth in Europe is led by the enforcement of energy efficiency regulations for buildings in the region and the need to reduce operating costs. Europe is also estimated to have the highest growth in the market on account of the increasing awareness about the benefits of advanced PCM and the level of commercialization of advanced PCM in the region. The USA is the second-largest market for advanced PCM and is projected to have a steady growth between 2014 and 2019. As Figure 7 depicts below on its left side, the distribution of PCM by application in the global market projected for 2022 still sees the building & construction segment holding a dominant position whereas in the right side image, the bio-based PCM is projected to register a compound annual growth rate (CAGR) of 15.8 % for the period between 2017 and 2022 [2].

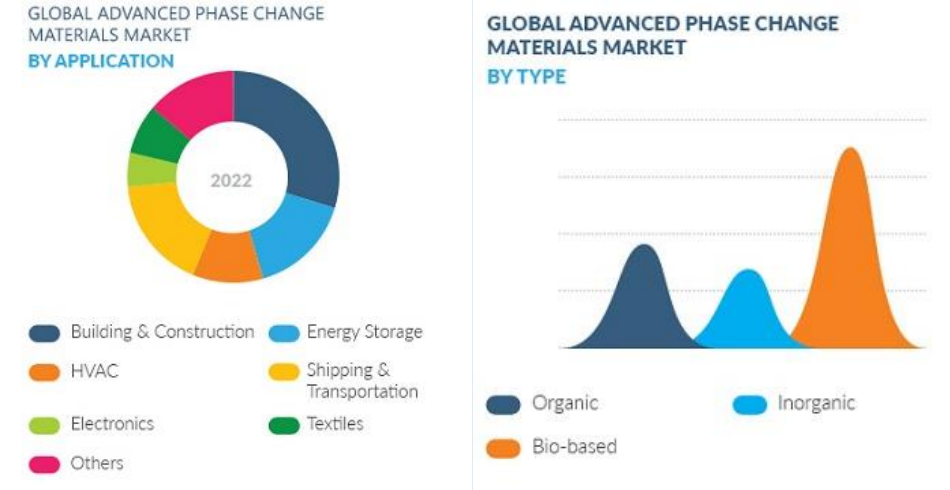

Figure 7. Global advanced PCM forecast for 2022 by application (left side) and by type of PCM (right side)

[2] Phase Change Materials Market Statistics 2024 | Industry Share Report, published on: February 2018 | 350 Pages | Report ID: GMI2241

In textile applications, PCM is used for comfort. An overarching growth driver for PCMs in textiles is the increased comfort of the apparel, but also for bedding and mattresses. The trend for smart textiles, the need for clothing without heat stress, and mattresses for comfortable restful sleep are driving the demand for encapsulated PCM (capsules can ensure a last long effect and wash resistance). Increasing acceptance of microencapsulated PCM in applications across bedding and mattresses, sports, and active wear expand consumption. For instance, the use of PCMs in mattress was evaluated at € 45.1 million in 2013. Microencapsulation of PCM improves its performance in the application, as the PCM can be uniformly distributed across the appropriate parts of the application. The advanced PCM industry is moving towards investments in the implementation of technologies to produce new and high-quality products. The present encapsulation technology has proved to be highly expensive and advancements in the area which is covered by the SKHINCAPS project will benefit the overall advanced PCM market in a considerable way. The companies involved in this market are extensively committed in research and developments of new products for specific applications and conditions.

DEVAN intends to persuade its costumers of the actual benefits of the nanoencapsulated phase change materials in comfort improvement as soon as all technical and regulatory requirements were met for safety and wash-resistance topic. Since the commercial channels are already in place, the time to market is forecasted for 2 years post-project duration and so DEVAN expects significant commercial results after prototypes are validated in a pre-industrial model with the aim to get an increase of 30% of the thermo-regulation business in bedding, which should represent a yearly turnover of 4 million €/year.

The project was funded by the Horizon 2020 Framework Programme of the European Union under grant agreement no. 685909. The project consortium comprises 8 partners: 4 research organisations – CeNTI (PT, coordinator), UPC (ES), IVW (DE) and VTT (FI) – and 4 industries – Bionanoplus (ES), Devan Micropolis (PT), TELIC (ES) and Pro-Active (BE).

SKHINCAPS was committed with the flagships initiatives, and with a number of wider Horizon 2020 objectives including: control healthcare expenditure, Horizon 2020 strategic cosmeceuticals sector and plural Horizon 2020 Key Enabling Technologies (KETs).