Development of a Phase Change Material (PCM) Measurement Methodology for Fabric Surface Quantification

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Phase change materials (PCMs) have unique chemical compositions that allow them to change phases from solids to liquids when a specific temperature is reached, providing a cooling sensation to the user. As skin temperature rises, the heat is absorbed and as the skin cools, the heat is released (Outlast, 2018). This type of active cooling technology was originally developed by NASA in the late 1980s for space suits and military applications (NASA, 2009). Today, PCMs can be found in a wide range of consumer apparel (McFarlin, Henning, Venable, Williams, & Best Sampson, 2016).

PCMs are often encapsulated in a polymer shell and applied as a finish to the fabric. Finishes may be classified by their useful life: temporary (last until conclusion of first cleaning cycle), durable (for life of product but diminishes over time), or permanent (for life of product with no diminishment) (Kadolph & Marcketti, 2017). The durability of PCM finishes over the material or product's useful life is not well known, nor is there a standardized procedure for quantifying the presence of PCMs on the fabric's surface.

Limited methods exist for identifying PCMs. Previous research has relied on highly specialized chemical detection equipment such as optical transmittance spectroscopy (Lu, Sun, Chen, & Gao, 2017), scanning electron microscopy (SEM), Fourier-transform infrared spectroscopy (FTIR), or gas chromatography mass spectrometry (GC/MS). In addition to being cost prohibitive and inaccessible, these devices require the user to know the chemical composition of the PCM prior to detection. However, due to their proprietary nature, this is often not disclosed to the supply chain customer. In addition, these methods, such as SEM, only detect the existence of the PCM and are not capable of quantifying the specific amount present (Shin, Yoo, & Son, 2004). To the researchers' knowledge, a reliable, valid, and cost feasible method for quantifying the presence of PCMs on a fabric's surface has not been established. Such a methodology is necessary to evaluate the durability of printed PCM finishes as part of the textile quality control process.

Therefore, the purpose of this research was to develop and analyze the efficacy of a microscopic evaluation methodology for fabric surface quantification of PCM finishes. A pilot study was conducted on 100% polyester athletic t-shirts with a proprietary encapsulated printed PCM finish applied to the back side of the fabric. Microscopic images were taken in three locations from each shirt at the same coordinates using a Nikon inspection microscope (iNEXIV VMA-2520 model) at 120X magnification (Fig 1.). Three shirts were assessed at new and after each home laundering interval: after 1, 5, 10, 20, 25, 35, 40, 45, and 50 washes.

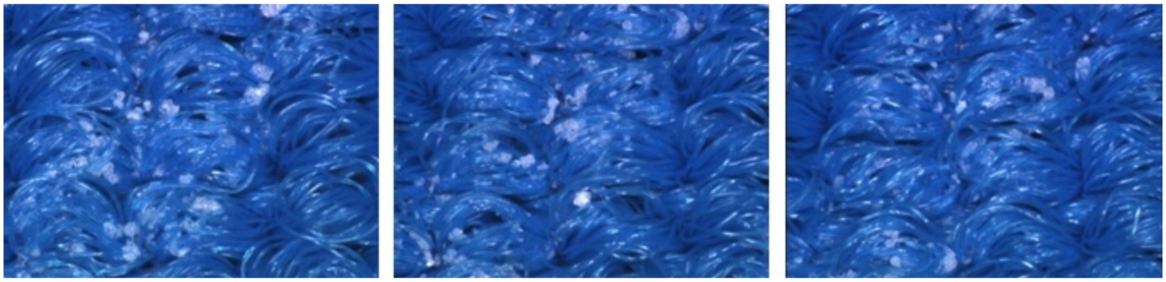

Figure 1. Images of the printed PCM finish on t-shirt #1 at new, after 25 washes, and after 50 washes (from left to right).

Images were then analyzed using Adobe® Photoshop® software tools. The total number of pixels in the original image was counted using the histogram function. A new layer was created overtop each original image and RGB red was applied where PCM particles were visible on the surface of the fabric (Fig. 2). The histogram function was again used to determine the specific number of RGB red pixels in the image. The percentage of PCM present on the fabric's surface, represented by the red pixels in each location, was calculated. The average percentage of PCM present on the fabric's surface after each wash interval is given in Table 1. After 50 consumer wash cycles, there was a 3.32% average decrease in PCMs detected on the fabric's surface. The largest measured reduction in PCMs on the fabric's surface (4.5%) occurred after 35 washes, demonstrating a non-linear pattern. This indicates a potential limitation of the developed methodology as the encapsulated PCMs may still be present within the fabric structure but not visible on the fabric's surface for quantification.

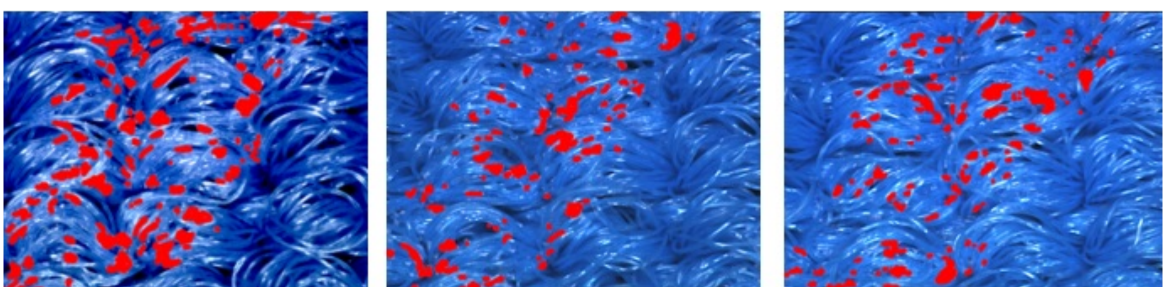

Figure 2. RGB red used to paint over PCMs on the surface of the fabric at new, after 25 washes, and after 50 washes (from left to right).

Table 1. Average percentage of PCM present on the fabric surface after each wash interval.

Wash Interval	Average % of PCM on Fabric Surface
New	11.11%
After 1 Wash	9.81%
After 5 Washes	8.14%
After 10 Washes	11.21%

After 20 Washes	12.18%
After 25 Washes	8.23%
After 35 Washes	6.61%
After 40 Washes	7.12%
After 45 Washes	9.13%
After 50 Washes	7.79%

Overall, the presence of the PCM on the fabric's surface diminished over the course of the garment's wash life. Results indicate the methodology developed within this pilot study was effective for fabric surface quantification. Limitations of the methodology include the inability to detect the PCM when it is not present on the surface of the fabric. Development of PCM detection methodologies is needed in the textile and apparel industry for quality testing purposes. Additional research should explore various microscopic techniques and software tools for improving the developed method. Other types of PCM finishes applied to different textile substrates should also be investigated. In conclusion, the developed methodology did prove effective for quantifying visual surface changes of the PCM finish.

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