Chemical Effects of Laundry Additives on Surface Resistivity of E-Textiles

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Wearables are electronic devices worn on the body, either as an accessory or integrated into clothing (ASTM Committee D13, 2020). Wearables have conductivity capabilities, advanced circuitry, and data communication functions. Growing since the 1970's, the wearable technology market is now a $32.63 billion industry, evolving to move data collection, analysis, and communication from smart devices directly to the body via sensors and electronic textiles (or e-textiles). Products made with fully integrated, wearable technology are referred to as 'smart clothing' or 'smart garments.' Due to their intimate contact with the human body, wearables become soiled and must be cleaned. One of the most significant challenges of smart garments is performance reliability post-laundering (Balsamo et al., 2017; Jansen, 2019; Rotzler, 2020). To achieve their full potential, wearable e-textiles (smart garments) must overcome these challenges to become everyday wear (Begovic Johnson, 2020).

An e-textile is "a fiber, yarn, fabric or end product comprising elements that result in an electrical or electronic circuit, with or without processing capability, or the components thereof" (ASTM Committee D13, 2020). Like traditional wearables, e-textiles send data to secondary devices where the user can evaluate the information. Most e-textile products are still in the research and development stage (Gonçalves et al., 2018), falling short in either functional performance, ease of use, production capability, price point, comfort, and/or maintenance, which includes washability (European Commission, 2016). Body soils may negatively impact smart garment functionality and also need to be removed for hygienic reasons. Thus, future wearables must be washable on-demand (European Commission, 2016). Current care instructions for e-textiles are limiting in terms of wash conditions. E-textile specification sheets may note that washing of any type (wet or dry) will eventually degrade metallic coatings and thus reduce functionality. When e-textiles are fully integrated into smart clothing, these laundry practices are inadequate for hygienic cleaning, inconsistent with behaviors of apparel consumers (Shin, 2000), and incompatible with garment longevity. Quantifying the impact of machine laundering conditions, specifically the impact of detergents or other additives, is crucial to establishing effective and realistic methods for repeatable care of smart clothing. In this study, the influence of detergents and laundry additives on e-textile surface resistivity is researched. The purpose of this study is to add to the body of knowledge pertaining to e-textiles and wash conditions which may contribute to the development of appropriate smart garment care labels, thus, assisting in the preservation of product functionality.

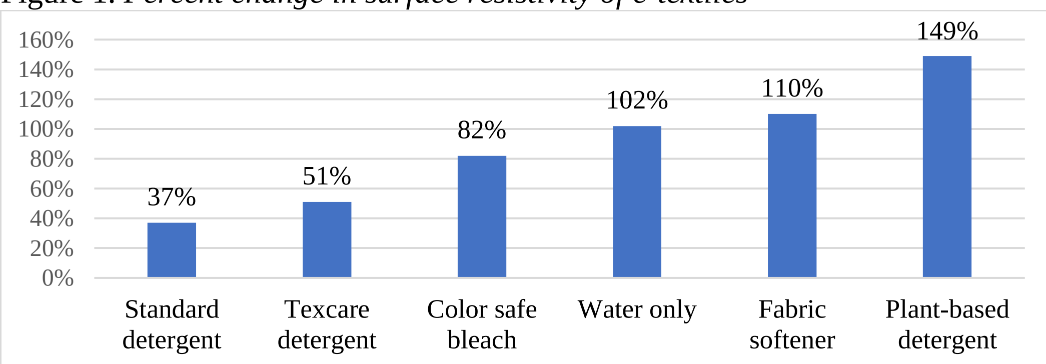
Seven e-textiles (see Table 1) were tested for a change in surface resistivity post-laundering. The detergents and other laundry additives were selected to represent a range of commonly used formulations and chemical laundering conditions. These include AATCC standard reference detergent, a detergent developed specifically for e-textiles (Texcare), a plant-based detergent, color-safe bleach, and fabric softener. All detergents and additives selected for use in this research study were free of colorants and perfumes.

Table 1. *Material properties of e-textile samples*

E-textile	Structure	Base Fiber	Weight	Conductor
ArgenMesh	Woven	Nylon	2.3 oz/yd^2	Silver
Cobaltex	Woven	Polyester	2.7 oz/yd^2	Nickel, copper, cobalt
Circuitex	Woven	Nylon	3.2 oz/yd^2	Silver
Nickel Copper Ripstop	Woven	Polyester	2.6 oz/yd^2	Nickel, copper
Silver Jersey	Knit	Cotton / polyester	4.8 oz/yd^2	Silver
Silver Mesh	Knit	Nylon	1.0 oz/yd^2	Silver
Ripstop Silver	Woven	Nylon	2.4 oz/yd^2	Silver

Laundering protocols were adapted from AATCC Test Method 61 Procedure 1B (*AATCC Test Method 61: Colorfastness to Accelerated Laundering*, 2013) to simulate five home launderings. Distilled water was used to reduce confounding factors related to tap water quality. Functional checks of surface resistivity were performed before and after laundering and air drying. Two replications were performed for each e-textile + chemical laundering condition, and measurements were taken in both warp/wales and filling/course yarn direction, resulting in 196 unique data points (28 for each chemical condition, including unlaundered).
<u>Analysis and Results:</u> For each combination of e-textile + laundering condition, average resistivity was recorded. Then, percent change was calculated and averaged across each chemical laundering condition (see Figure 1). Significant discoloration was noted to e-textiles with silver coated nylon washed in plant-based detergent.

Figure 1. *Percent change in surface resistivity of e-textiles*



Ionization of wash water appears to have strongly impacted e-textile surface resistivity and is responsible for the observed tarnishing/discoloration. Reviewing resistivity measurements post-laundering, it was observed that standard detergent outperformed all other additives under review. This may be explained by its higher concentration of corrosion inhibitors and builders, which have been shown to prevent water ions to bind with minerals commonly found in water (Bajpai & Tyagi, 2007). Plant-based detergent showed the greatest percent change in surface resistivity. This is speculated to be due to the chemical reaction between metals and enzymes (Reidy et al., 2013), which were present only in the plant-based detergent. Poor performance of fabric softener may be related to residual residue. The findings of this study have helped make advancements towards understanding how e-textiles respond to laundering conditions.

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