Launderability of Stitched Surface-Mount E-Textiles

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Introduction: Embedded electronic technology has the potential to greatly enhance and augment the functionality of clothing and other wearable products. For garment-integrated applications the needs of the embedded system must be balanced with the needs related to interacting with the garment itself – in terms of qualities like comfort, hand-feel, and maintenance behaviors. While consumers in general expect to be able to launder e-textile garments in the traditional manner, launderability presents additional challenges for durability of electronic-textiles (e-textiles).

Background: Launderability is a challenge for e-textiles due to both the chemical interaction of the e-textile circuit with detergents and moisture and the mechanical effects of the intense environment of the washer and dryer (Wang, 2016; Cherenack and Pieterson, 2012). Most existing approaches to improving the launderability of e-textile garments require compromise of other interaction properties, particularly mechanical properties (but also properties like breathability and aesthetics) (Zeagler, 2013). Here, we investigate the launderability of an e-textile fabrication technique that aims to preserve textile and garment properties by minimizing the impact of integrated electronics through component distribution, stitched assembly methods, and minimization of integrated hard goods.

Methods: In this study, the stitched e-textile circuit fabrication method developed by Berglund et al. (2015) and Islam Molla et al. (2017) was used. (Method details available in those references). A total of 40 samples (containing a total of 200 LEDs and 400 solder joints) were fabricated for launderability testing. 10 samples with 5 LEDs each were produced in each of 4 conditions: varying the textile substrate (100% cotton with twill weave and 80% polyester & 20% cotton with twill weave, both pre-washed), as well as the LED package size (5 mm 6-PLCC packages and 3mm 1206 packages were tested, as shown in Figure 1).

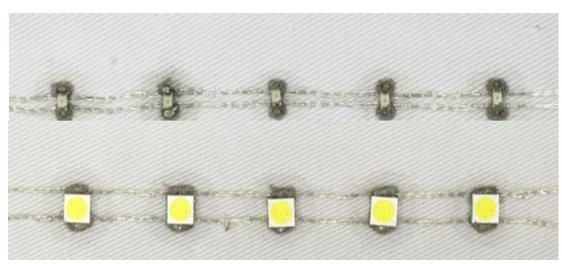

Figure 1. E-textile samples using 3 mm (top) and 5 mm (bottom) LEDs.

The wash test method used was based on typical home laundering: machine washing and drying. Whirlpool® Ultimate Care II washing and tumble-drying machines were used for all wash and dry cycles in this study. All® "Free and Clear" detergent was used with all washing cycles. All samples underwent 10 complete washing and drying cycles (1000 minutes). High-intensity ("Cotton/Heavy" wash cycle paired with "High" drying) and low-intensity (Hand Wash/Wool wash cycle paired with "Extra-Low" drying) conditions were tested. Test parameters for both conditions: extra-small fill level, "cold" water temp, 2.4 oz detergent, 40 min wash cycle, 60 min dry cycle. After each cycle, all LEDs were tested and failures recorded, and all failed joints were photographed using a 30X microscope lens.

Results and Discussion: At the test conclusion, we measured a 1.5% failure rate (6 out of 400 solder joints) across all conditions. Both textiles experienced 3 failed connections (1.5%). While it was hypothesized that a stiffer fabric might provide more strain relief for solder joints, fabric structure perhaps did not have a significant impact on the overall connection failures. All observed failures happened between the component-attached solder and the conductive trace. Of the two package sizes, the 3mm package had the weakest connections with a total of 6 connection failures, while 5mm package had zero connection failures. The same failure rate (1.5%) was measured for both intensity conditions.

Conclusion and Future Work: These results demonstrate the feasibility of this technique for machine-launderable e-textile garments. Further improvement in the process will increase overall launderability and durability of the samples. One limitation from this study is that it measures only solder joints and not trace resistance, which would reflect the effects of washing on the embedded conductive traces in addition to the solder joints. In future, the use of insulated traces might improve their durability, but attention must be paid to the effects of insulation on both manufacturability and on wearability parameters like stiffness and breathability.

Acknowledgments

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