

# Electrical connection issues on wearable electronics

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**Abstract.** The drive for integration of electronic components into textile substrates has been a major aspect of research into production of smart textiles. Electronic components as such, are rigid, inflexible, do not easily follow body movements and can cause hypersensitivity of the skin upon prolonged contact due either to the presence of irritants or the rigid nature of the materials. Another important disadvantage of electronic components, in wearable applications, is that while textiles and textile like materials can withstand the usual cleaning/ care treatments, those same treatments can have detrimental effects on the transmission lines and on any exposed electronic parts. This paper investigates a method for the protection of transmission lines made of conductive yarn seams on specimens containing both electronic and textile elements integrated on a textile substrate as well as the protection of the electronic parts. The reliability and durability of the transmission line on the combined specimen is determined by the measurements of the value of an electrical resistance located on a rigid PCB, after repeated wash cycles.

## 1. Introduction

Innovative smart textile structures [1-4] that endeavour to incorporate electronic components usually face a host of difficulties that stem from the fact that textile structures and textile materials in general are characterised by a quite different set of characteristics, that can seem incompatible with the characteristics of electronic components. Apart from the requirements for high flexibility, conformity to body shape, in wearable applications, while textiles and textile like materials are designed to withstand the usual cleaning/ care treatments, those same treatments can have detrimental effects on the transmission lines and on any exposed electronic parts [5-7].

The research described in this paper, was carried out within the framework of Project Welding of E-Textiles for Interactive Clothing-E-TexWeld. The aims of the project are i) the design of transmission lines of e-textile structures, ii) integration of electronic elements (different sensors,



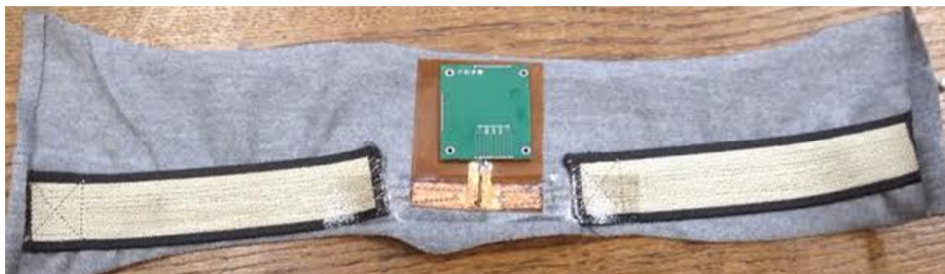
actuators, microprocessors, data transmission and power supply systems) to textile structures, and ii) the design and development of whole e-textile system for protective clothing applications including interactive protective garments and shoes. A significant application of personal protective equipment is the bunker gear or turnout gear used by firefighters when they need to handle an incident. This turnout gear mainly consists of a multilayered-jacket and multilayered-trousers (as well as boots). The layers of the uniform usually consist of fabrics made off a mixture or pure aramid fibres. One of the most well-known companies producing fibres and fabrics specifically for firefighter PPE (personal protective equipment) is DuPont with the trademarked Nomex flame-resistant meta-aramid material.

Protection of the electronic components of the combined specimens was carried out using two strategies; the rigid PCB containing the electrical resistance was encapsulated using silicon, and the conductive seams, comprising the transmission lines were covered on both sides of the textile substrate (single jersey knitted fabric), using TPU (thermoplastic polyurethane) thermoplastic film.

## 2. Materials - Methods

### 2.1. Materials

The combined specimens (Figure 1) consist of textile and electronic elements integrated on a single jersey knitted fabric (100% Nomex). The electronic elements comprise of a rigid printed circuit board (PCB) that includes a 10 Ohm resistance. The PCB is soldered onto electrodes made of flexible PCB (Kapton). Then the PCB is encapsulated in silicon. The textile elements are textile-based EKG electrodes (provided by TTRI Taiwan Textile Research Institute), which are connected by conductive thread seams, to the flexible PCB electrodes. The conductive thread (Shieldtex 234/34-2 ply HC) is silver coated polyamide. The thread is two-ply with a fineness of 234dTex and 32 filaments per thread ply (total of 68 filaments); its linear resistance is less than 100 $\Omega$ /m. All conductive thread seams are covered by a thermoplastic polyurethane (TPU) film (thickness 1mm) on both sides of the seam. The TPU film is thermoset using a press at 180 °C for 20sec.



**Figure 1.** Test specimen before encapsulation of the rigid PCB

### 2.2. Methods

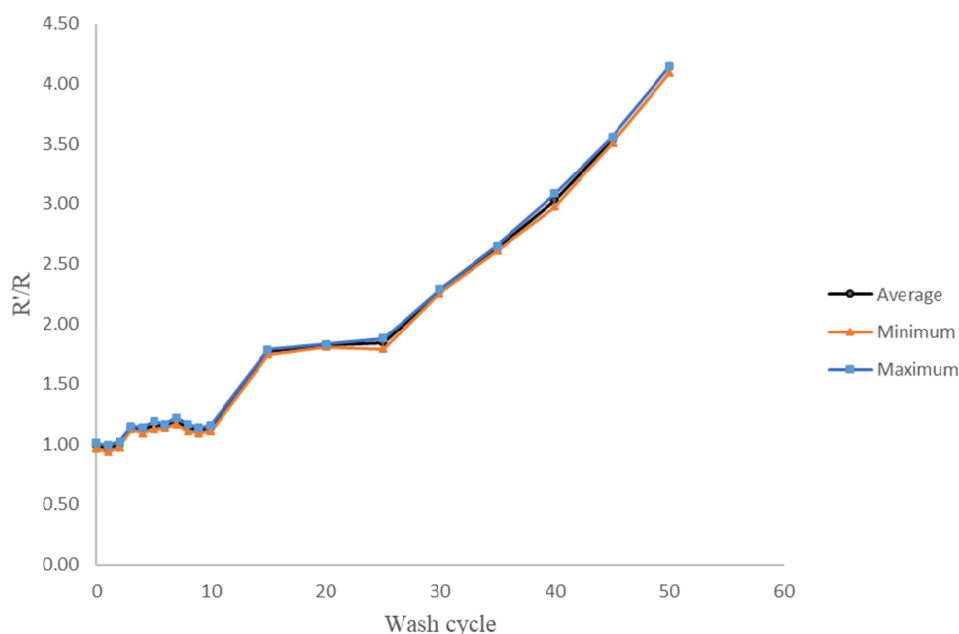
*Washing test.* In order to test the durability of the combined specimen, successive washing cycles were carried out. Washing was realized according to ISO 6330 [8] which describes standard washing and drying procedures for textiles. The washing temperature was 40°C and the duration was 30 mins using a Datacolor Ahiba IR laboratory dyeing machine. Between washing cycles, but not necessarily between every cycle, specimens were drip dried and their functionality was determined. Fifty wash cycles were carried out in total.

*Measurement of electrical resistance.* The value of the resistance on the rigid PCB was measured on the EKG electrodes after each wash, up to and including the tenth wash and every five washes after that up until the fiftieth wash cycle. The nominal value of the resistance on the dummy PCB is 10 Ohm however when measured on the ECG electrodes the value is 12.83 Ohm. This resistance is the sum of resistance on the rigid PCB, the resistance of the flexible PCB, the resistance of the conductive yarn seams, the resistance of the ECG electrode as well as the sum of the contact resistances between the conductive thread the flexible PCB and the ECG electrodes.

### 3. Results and Discussion

The evolution of the value of the mean resistance measured on the EKG electrodes during the full set of the 50 wash cycles can be seen on Figure 2. The values of the minimum and maximum resistances measured are also plotted on Figure 2. All measurements have been normalised by dividing them with the value of the resistance measured in the pristine condition. The values of the minimum, average and maximum values measured on the EKG electrodes don't appear to vary significantly as can be seen in Figure 2. This can be attributed to the very high conductivity of the EKG electrodes.

After the fiftieth wash cycle the mean resistance was approximately four times the value of the resistance of the pristine specimen, which is considered an acceptable value for EKG applications. The behaviour of the resistance of the combined sample is in concordance with the behaviour observed in the research by Tao et al. [9] who also carried out washing tests on samples containing conductive threads and flexible PCB electrodes. This increase in the value of the resistance is considered to be connected with an increase of the contact resistance between the fibres of the conductive thread and the EKG electrodes. From the macroscopic examination of the specimens no defects were detected either on the areas covered by the TPU tape (peeling, cracking), or on the silicon coating of the rigid PCB.



**Figure 2.** Resistance measurements vs number of wash cycles

### 4. Conclusions

This study was carried out within the framework of ETextWeld project. One of the goals of the project is the integration of electronic elements (various sensors, actuators, microprocessors, data transmission and power supply systems) to textile structures. Integration usually fails due to the weakness of electronic elements to the usual cleaning/ care procedures commonly used for garments (most often washing in a detergent solution with added agitation). Based on the results of this study, we can conclude that use of silicon to encapsulate electronics vulnerable to contact with water and mechanical action appears to ensure their functionality even after 50 wash cycles. Moreover, the thermoplastic polymer film offers satisfactory protection for the conductive silver coated thread used for the transmission lines.

## Acknowledgments

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