2.1. Enhancing E-Textile Reliability: A Comparative Study of SMD-Ribbon Joints Protections Against Sweat

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ABSTRACT

The reliability of electronic-textile (e-textile) systems is critically influenced by environmental factors such as sweat, which can compromise the performance of smart textile garments in sports and healthcare applications. This study investigates the durability of joints between surface-mount device (SMD) chip resistors and conductive textile ribbons under accelerated aging conditions simulating exposure to synthetic sweat. Two types of sample protection were evaluated: basic encapsulation using a UV-curable adhesive, and additional protection employing seam-sealing textile adhesive tape. SMD resistors were attached to silver-coated copper microwire ribbons using a specialized contacting technique, and their joint resistance was monitored across four cycles of immersion in acidic synthetic sweat, high-humidity aging, and drying. Results demonstrate that while joints with only basic protection exhibited increasing electrical resistance and frequent failures after repeated aging cycles, those with additional seam-sealing protection maintained low and stable resistance, with no observable degradation. These findings confirm that the interface between textile substrates and electronic components is a critical failure point in e-textile systems, and that the use of seam-sealing adhesive tape significantly enhances connection reliability and longevity. The presented contacting and protection approach is recommended for robust integration of SMD components in smart textiles intended for demanding environments

INTRODUCTION & THEORY

In recent years, the field of e-textiles—textiles integrated with electronic components—has emerged as a significant and rapidly expanding market. These e-textiles integrate electronic functionality into flexible substrates, enabling applications in healthcare (wearable biosensors for physiological monitoring [1]), military/sports performance optimization (real-time sweat analysis via graphene-based textiles [2]), and safety systems [3], etc. Our research in this field has revealed insights into the behavior and durability of e-textile products and their components. One of the materials used in these textiles are electrically conductive ribbons, which are flexible and stretchable. Our previous experiments have demonstrated the feasibility of creating electrically conductive contacts between passive components and these ribbons through gluing or soldering techniques [4]. However, a crucial question arises regarding the reliability of these connection methods in various operational environments.

Passive components, such as resistors, capacitors, and inductors, play a vital role in e-textile systems. These components do not require a power source to operate and are essential for controlling electrical current flow, storing energy, and filtering signals. In e-textiles, SMD versions or fully printed versions of these passive components are preferred due to their compact size and suitability for textile substrates. SMD are well-suited for e-textiles due to their natural contact with conductive pads, which can be easily created on textile substrates.

Sustainable manufacturing is currently a very important topic that also appears in connection with e-textiles. Heterogeneous integration approaches using screen-printed graphene [2] or recyclable thermoplastic adhesives [5] address e-waste concerns. Lifecycle analyses suggest that modular designs with separable interconnects could reduce textile electronic waste by 65% compared to fully integrated systems [6].

Accelerated degradation primarily occurs at the textile-component interface due to mechanical stress, chemical exposure, climatic factors, etc. Our long-term observations indicate that e-textile products and electrical joints tend to exhibit degradation at a significantly accelerated rate compared to the SMD components themselves. This finding suggests that the interface between the textile substrate and the electronic components and whole conductive paths in substrate are a critical point of failure in e-textile systems.

MATERIALS & PROCEDURES

E-textiles must withstand diverse conditions influenced by multiple factors. Sweat, for instance, can be a significant factor affecting smart textile sports or healthcare garments. To address this, we have investigated the reliability of joints between SMD chip resistors (a common type of passive component) and textile ribbons during accelerated aging by synthetic sweat. By focusing on the behavior of passive components and their connections in challenging environments, we aim to improve the longevity and reliability of e-textile products. This study investigates the reliability of connections between passive surface-mount device (SMD) components and conductive textile ribbons in smart textiles under accelerated aging conditions.

Based on assumptions from our previous research, we set two basic hypotheses. The first hypothesis is that the electrical resistance of joints between SMD components and conductive textile ribbons will remain stable during accelerated ageing by synthetic sweat. The second hypothesis is that additional protection of the joints and conductive paths by seam-sealing textile adhesive tape will improve the reliability of the connections and whole ribbons under harsh conditions.

In the experiment, the conductive textile stretchable ribbons with silver-coated copper microwires and examined two sample types were utilized: basic protection (encapsulation) and additional protection. For each type, ten SMD chip resistors (case size 1206) with theoretically resistance approaching zero were attached to the ribbons using a special contacting technique. The declared value by the manufacturer is under 20 mΩ, but we measured the real resistance with median value 8.2 mΩ in our previous experiment [4]. Our special contacting technique involved dispensing non-conductive UV-curable adhesive onto the textile ribbon by using dispenser. Then, careful mounting the SMD components onto the conductive paths on the ribbon, and applying defined pressure (typically around 25 MPa) using a metal rod on the components. The adhesive is moved by this pressure from the area under the component leads and the direct intimate contact of component pads and conductive wires in the ribbon ensure the electrical connection. Then the adhesive is cured by UV light under constant pressure to make mechanical fixation of electrical connection. Finally, the rest of the component is encapsulated by the same adhesive which creates the basic protection. The principle of our technique can be seen in Figure 1.

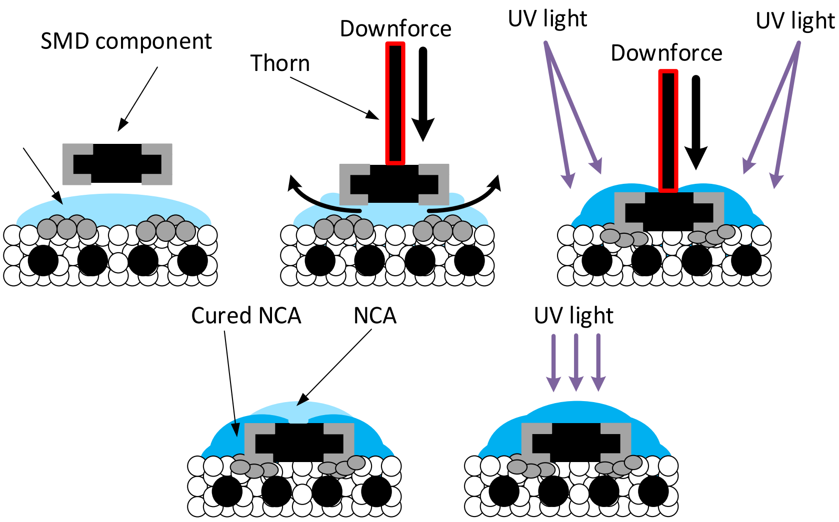

Fig.1. The principle of SMD component connection onto the textile ribbon by our special contacting technique.

The additionally protected samples are prepared similarly, but the protective seam sealing textile adhesive tape is used for additional protection of joints and conductive lines. This tape consists of nylon and polyurethane materials. In the first step, this tape is cut to the appropriate length in two pieces (upper and lower side), and the circle hole with diameter 5mm is prepared by CO_2 laser in the middle of upper tape. Then the measurement leads are crimped onto the conductive path in ribbon and the ribbon is placed onto the lower tape. In the next step, the polyurethane grid is placed on the ends of the ribbon where the crimped leads are connected. Finally, the upper tape is placed and the whole sandwich structure is inserted into the heat press machine. The parameters of press are follows: temperature 120°C, pressure 500 g/cm^2 for 30 seconds from each side. The individual components and final sandwich can be seen in Figure 2. After the finalizing of additional protection, the SMD component is connected and encapsulated to the sandwich by the same conducting technique from basic protection.

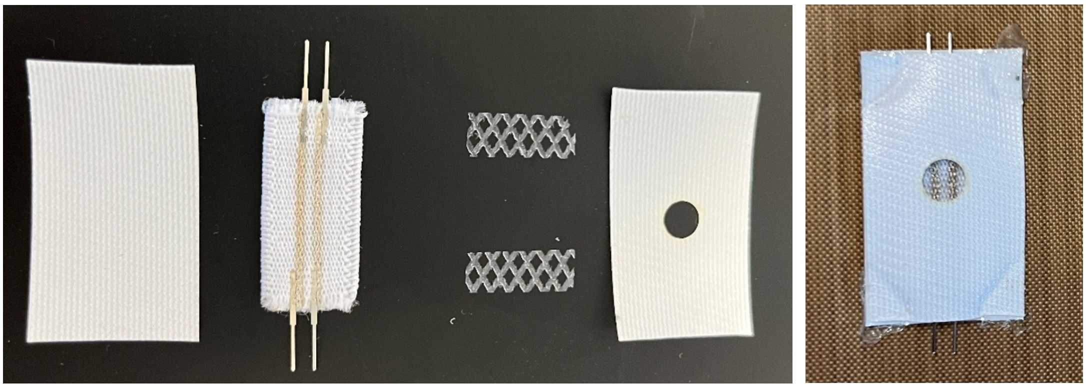

Fig.2. The components used for the samples with additional protection (left); final sandwich before press (right).

The electrical resistance of the joints is measured using a four-point probe method with a Keithley DAQ6510 device. The measurement was systematically performed before, during and after sweat ageing. The samples underwent four cycles of accelerated aging, each comprising immersion for 2 hours in highly acidic synthetic sweat (pH 4.4, prepared according to a modified ISO 105-E04 standard), followed by high-humidity aging (40°C, 93% RH for 164 hours), and drying (40°C, 40% RH for 2 hours). The electrical resistance of the joints was measured after each cycle. The testing procedure can be seen in Figure 3. Statistical analysis was performed to compare the results of the two sample types, providing insights into the durability and reliability of these connections in smart textiles exposed to harsh environmental conditions.

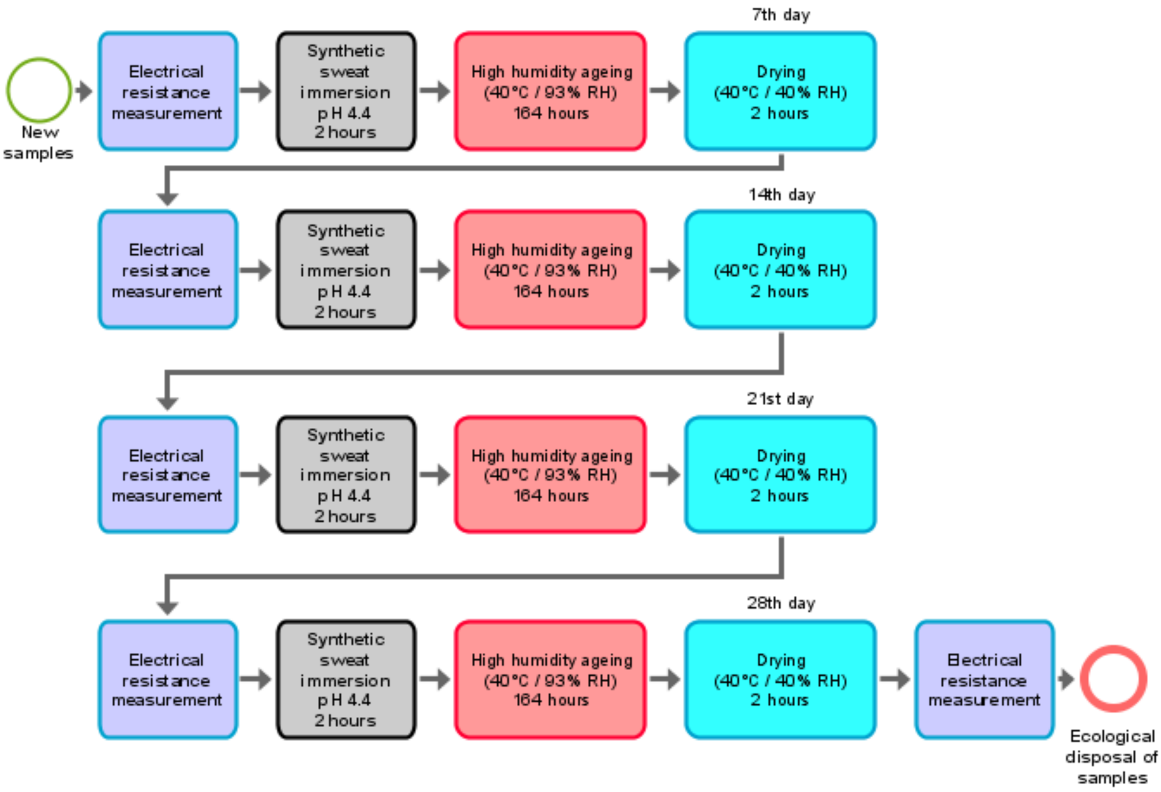

Fig.3. Testing procedure.

RESULTS & DISCUSSIONS

The measured values of joints electrical resistance from the experiment were statistically analyzed and the bar chart and boxplot diagrams were prepared, see Figures 4 and 5. The results show that electrical resistance of joints for samples with additional protection during ageing by sweat is low and relatively stable with the exception of outliers. The results of samples with basic protection only show that electrical resistance grows during the ageing and from the second cycle onwards, even destroyed samples appear, in which the electrical resistance is no longer measurable.

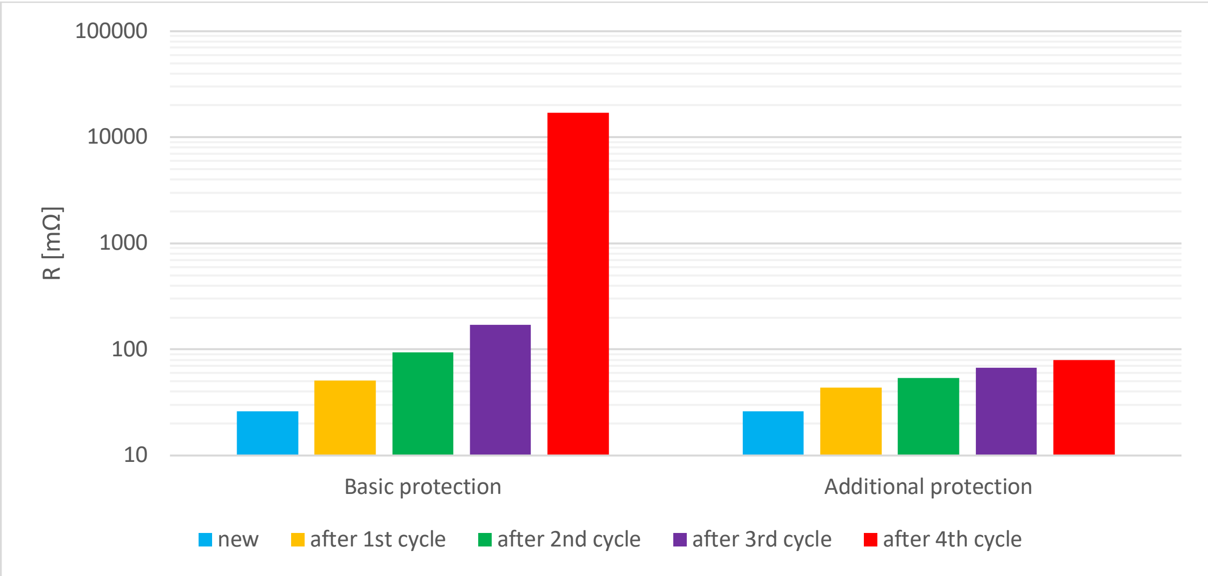

Fig.4. Bar chart diagram of joints electrical resistance medians during the ageing

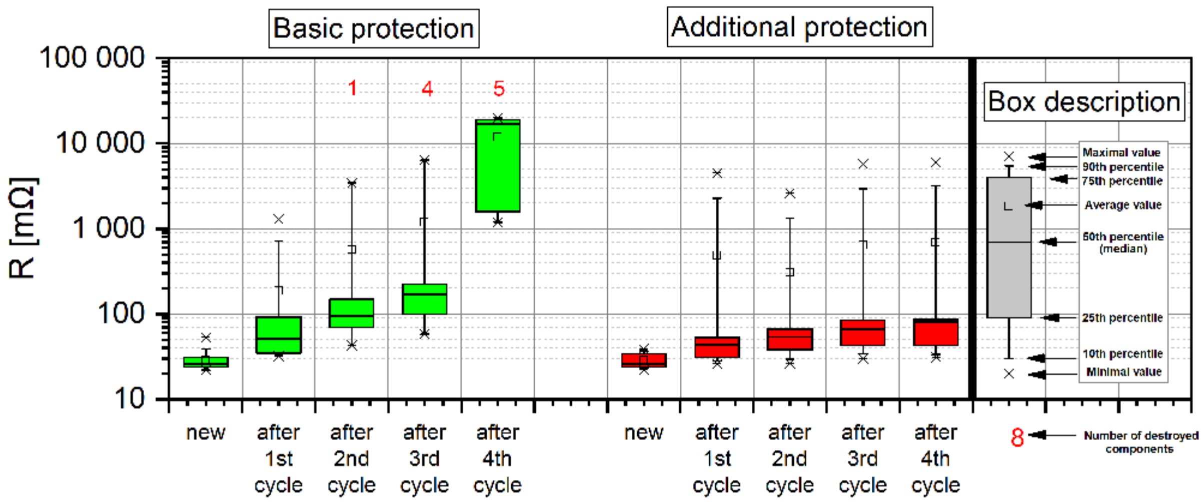

Fig.5. Boxplot diagram of joints electrical resistance during the ageing cycles.

The samples were further subjected to optical inspection (see Figures 6 and 7), which shows that in the case of the sample with basic protection, degradation of conductive paths in the ribbon is visible. Degradation under the component is not visible from these images but based on the results we assume that it occurs mainly from the underside of the ribbon where the basic protection is not applied. The samples with additional protection do not show any visual degradation. Finally, we subjected these samples to a destructive test, in which we tried to remove the protection with a sharp scalpel and got into the ribbon structure. However, no degradation was visible even when observing inside the ribbon for these samples with additional protection.

Fig.6. The prepared samples before ageing.

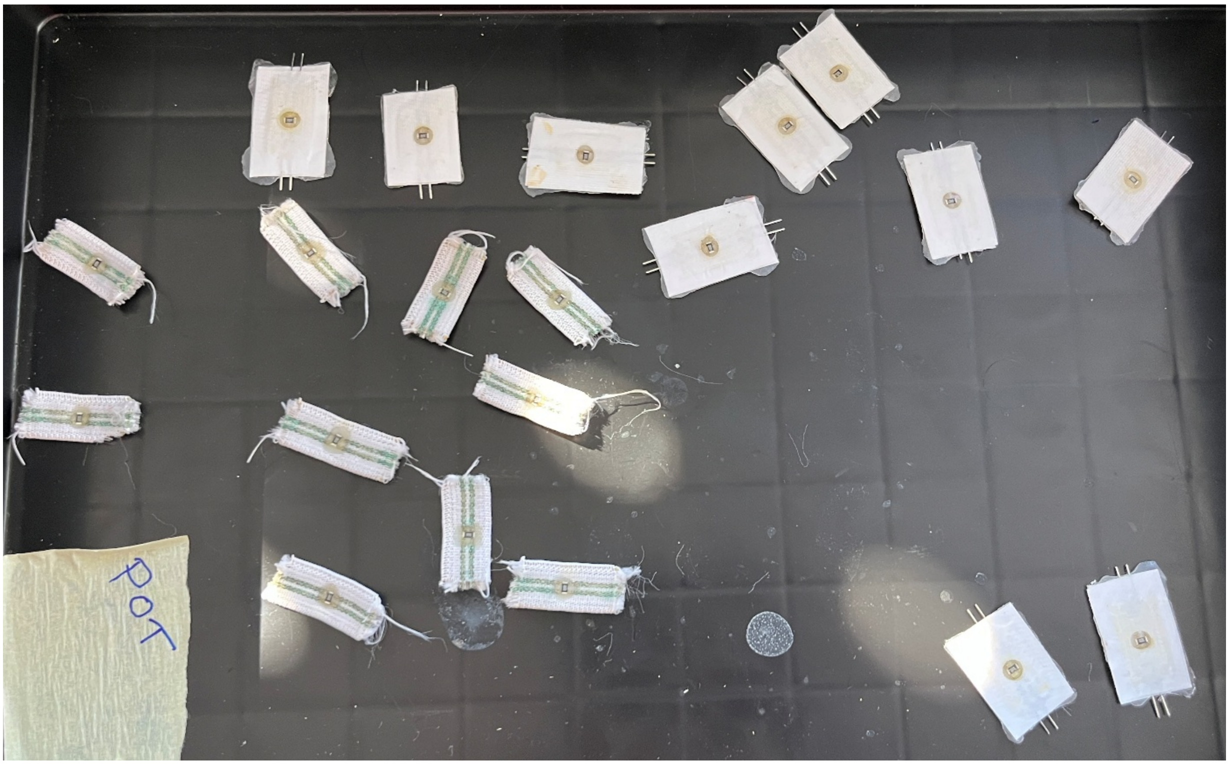

Fig.7. The samples after ageing by synthetic sweat.

SUMMARY & CONCLUSIONS

The results of accelerated ageing tests of SMD chip resistor joints on conductive textile ribbons using our special contacting technique demonstrate that the method shows potential for e-textile applications, but the level of protection plays a crucial role in the long-term reliability of the connections. The first hypothesis, that the electrical resistance of joints between SMD components and conductive textile ribbons will remain stable during accelerated ageing by synthetic sweat, was fully confirmed only for samples with additional protection. For samples with basic protection, the hypothesis was not confirmed, as a significant increase in electrical resistance and even total failure of some joints was observed from the second ageing cycle onwards.

The second hypothesis, that additional protection of the joints and conductive paths by seam-sealing textile adhesive tape will improve the reliability of the connections and whole ribbons under harsh conditions, was fully confirmed. The samples with additional protection exhibited low and stable electrical resistance throughout all ageing cycles, and no visual or structural degradation after inspection was detected. In contrast, samples with only basic protection showed visible degradation of conductive paths and a clear trend of increasing electrical resistance, indicating insufficient durability for demanding applications.

It can be concluded that the interface between the textile substrate and the electronic component is a critical point of failure in e-textile systems, especially under exposure to sweat and high humidity combined with flexing and stretching. The use of additional protection, such as seam-sealing textile adhesive tape, significantly enhances the reliability and longevity of these connections. For practical applications in smart textiles, especially in environments with increased exposure to sweat or humidity, we fully recommend the use of additional protection. The presented contacting technique, in combination with appropriate protection, provides a reliable solution for integrating SMD components into flexible textile substrates.

ACKNOWLEDGEMENT

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