Protective Coating Methods for Glove-Integrated RFID Tags - A Preliminary Study

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***Abstract*—In this study, machine washing durability of working glove-integrated passive RFID tags is evaluated. These glove-tags are embedded inside 3D-printed thermoplastic polyurethane platforms. The results are compared to platforms embedded inside brush-painted encapsulant platforms. For a preliminary washing reliability evaluation, both types of glove-integrated platforms are washed in a washing machine for 5 times. Although both platforms can protect glove-tags from the effects of water, the main reliability challenge is found to be the fragile antenna-IC attachments. This paper introduces the two platform materials and the achieved washing test results. These preliminary results determine the future direction of this research: The next step is to study suitable methods to strengthen the interconnections, so that these glove-tags can survive the harsh environment inside a washing machine.**

***Index Terms*— Gloves, passive UHF RFID, protective coatings, reliability evaluation, washing.**

I. Introduction

Passive ultra-high frequency (UHF) radio frequency identification (RFID) technology is one of the technologies that have been recently integrated into textiles for versatile applications of wearable electronics [1]-[4]. With the help of 3D printing technology, intricate and detailed structures can be easily manufactured. Thus, 3D-printable materials, especially 3D-printable thermoplastic elastomers, have been recently used for fabrication of antenna substrates and wireless platforms [5]-[10].

In a previous experiment [11], glove-integrated passive RFID tags, embedded inside 3D-printed thermoplastic polyurethane platforms, were developed and evaluated. In that study, the developed glove-tags were found to endure exposure into water. Thus, the next step is to evaluate their washing reliability. Washing machine combines the effects of moisture and mechanical stresses. Thus, it creates an extremely challenging environment for textile-integrated electronics. For comparison, a stretchable protective encapsulant is selected. Similar encapsulant has been found to effectively protect textile RFID tags from moisture [12]. In [12], RFID tags were cut from electro-textile, embroidered with conductive thread, and painted from conductive paint. The used substrate was 100 % cotton fabric. Although the coating was found to protect the textile tags from moisture, the mechanical stress during washing cycles was detrimental for the tag performance. However, since we are now working with a much thicker fabric (the used gloves are normal working gloves, as presented in Fig. 1), we want to test the washing reliability of these glove-tags also with a protective encapsulant material. Thus, both types of glove-tags are fabricated and washed in a household washing machine for 5 times. This paper introduces the two platform materials and the achieved washing test results.

II. Glove-Tags inside protective platforms

The electro-textile material is nickel-plated Less EMF Shieldit Super Fabric, exhibiting a sheet resistance of 0.16 Ω/□. From this material, the antenna pattern is cut using Epilog Fusion 12000 laser cutting machine. These antennas have hot-melt adhesive on the backside, and they are ironed to normal working gloves. The RFID integrated circuit (IC) is NXP UCODE G2iL RFID IC. This IC component is attached by the manufacturer to a thin plastic substrate, which has two copper pads for simple attachment to the antenna. In this study, these copper pads of the ICs are attached to the antenna pattern using conductive silver epoxy. A ready-made tag attached on a glove is presented in Fig. 1.

Fig. 1. Glove-tag without protective platform.

As described with details in [11], these electro-textile RFID tags are embedded inside 3D-printed thermoplastic polyurethane platforms. The used material is NinjaFlex from NinjaTek [13]. Two types of platforms are tested: 1) platform without base layer, i.e., where the tag is attached directly to the glove 2) platform with a base layer, i.e., where a base layer of thermoplastic elastomer is first printed under the tag. The thickness of the top and bottom layers are 0.3 mm and 0.1 mm, respectively. Two samples of each type are fabricated. A readymade tag inside a thermoplastic elastomer platform is shown in Fig. 2.

Du Pont PE773 Stretchable Encapsulant for wearables [14] is used as another platform material. The encapsulant platform is fabricated manually by brush-painting. Due to the manually done coating process, the coating layer is not uniform. This protective material is cured at a temperature of 100 ˚C for 30 minutes. Similarly, two types of platforms are tested: 1) platform without base layer, i.e., where the tag is attached directly to the glove 2) platform with a base layer, i.e., where a base layer of encapsulant is firstly painted under the tag. Two samples of each type are fabricated. A readymade tag inside an encapsulant platform is shown in Fig. 2.

Fig. 2. Readymade glove-tag inside thermoplastic polyurethane (top) and stretchable encapsulant (bottom).

III. Measurement and Testing Setup

Voyantic Tagformance RFID measurement system is used for the wireless measurements. It comprises of an RFID reader whose transmission frequency can be adjusted in the range of 800 MHz – 1000 MHz, and an adjustable output power, which can reach up to 30 dBm. It provides the backscattered signal strength of the tag being tested down to -80 dBm. Initially, the system's reader antenna and the position of the tag antenna is calibrated with a reference tag. The measurement of the theoretical read range between the reader antenna and the tag under test is evaluated based on (1),

$$d_{Tag} = \frac{\lambda}{4\pi}\sqrt{\frac{EIRP}{P_{TS}L_{fwd}}} \quad (1)$$

where EIRP is the Effective Isotropic Radiated Power (3.28 W, emission limit set within the European countries), λ is the wavelength of the reader antenna's transmission, P_{TS} and L_{fwd} are the measured threshold power and forward losses, respectively. We are conducting all the measurements inside an anechoic chamber.

The washing tests are conducted in normal household washing machine. All the glove-tags are washed in 40 °C for 5 times. Each washing cycle lasts for 45 minutes. The tags are measured after each washing cycle, once they have completely dried in office conditions (for around 24 hours).

IV. Results and Discussion

The achieved read range results before and after washing cycles, in the range of 800 MHz – 1000 MHz, are presented in this chapter.

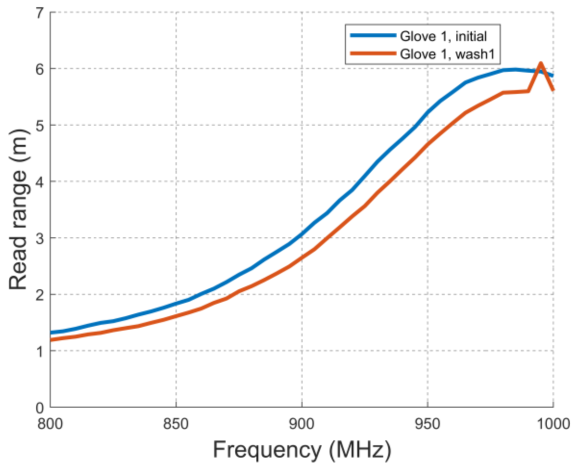

Fig. 3. Read range results of a glove-tag inside a thermoplastic polyurethane platform (no base layer).

Fig. 3 shows read range results of a glove-tag inside a thermoplastic polyurethane platform (no base layer). As shown, it has an initial peak read range of about 6 meters. After the first washing cycle, the tag still seems to work well. However, after the second washing cycle, there is no response from the tag. Further, the other sample stops working already after the first washing cycle.

Fig. 4 shows read range results of a glove-tag inside a thermoplastic polyurethane platform (with base layer). As can be seen, it shows an initial read range of about 5.5 meters and maintains its performance after all 5 washing cycles. However, the other sample stops working after 4 washing cycles.

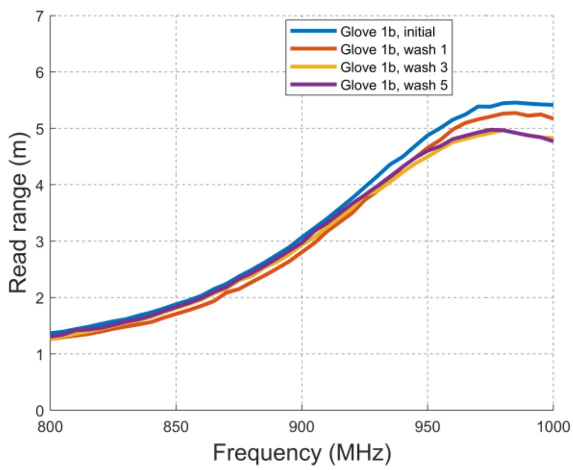

Fig. 4. Read range results of a glove-tag inside a thermoplastic polyurethane platform (with base layer).

Fig. 5 shows read range results of a glove-tag inside a protective encapsulant platform (no base layer). As shown, it has an initial peak read range of almost 7 meters. The tag remains functional through the 5 washing cycles but washing causes a decrease to the read range. The other sample remains functional only after the first washing cycle.

Fig. 6 shows read range results of a glove-tag inside a protective encapsulant platform (with base layer). Also, this tag shows initial read range of more than 6 meters. The tag remains functional for 2 washing cycles, but the performance decreases significantly after the second washing cycle. The other sample stops working after 3 washing cycles.

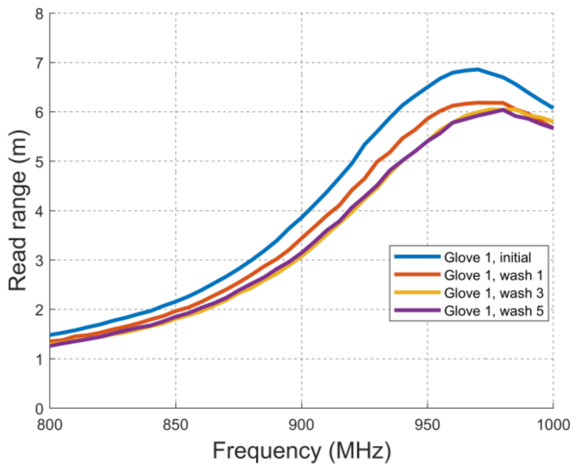

Fig. 5. Read range results of a glove-tag inside a protective encapsulant platform (no base layer).

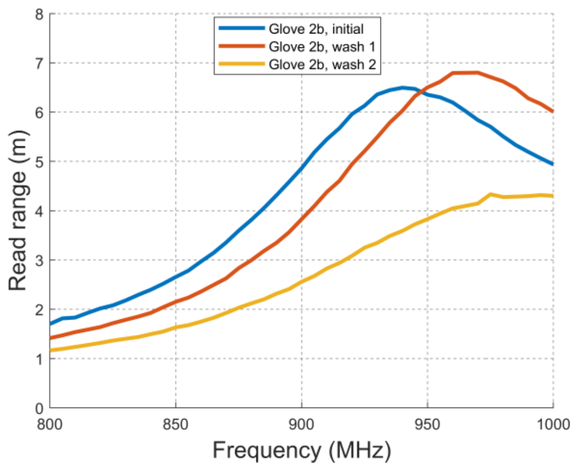

Fig. 6. Read range results of a glove-tag inside a protective encapsulant platform (with base layer).

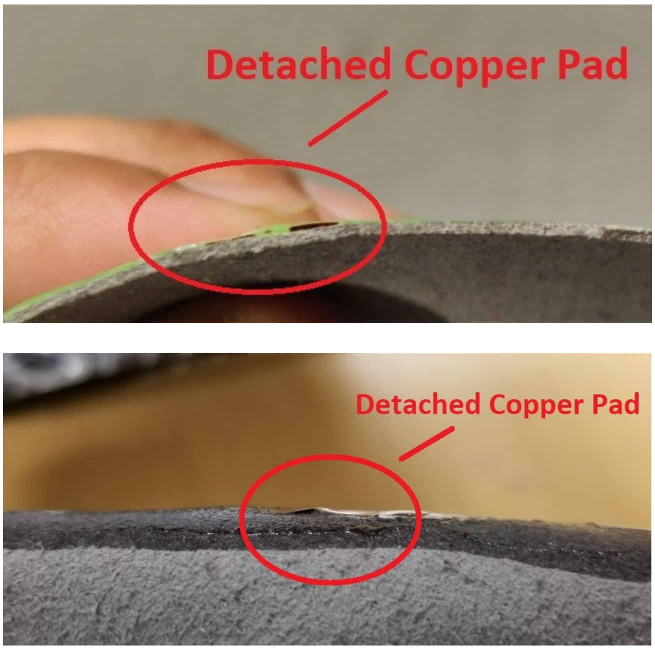

Fig. 7. Copper pads of RFID ICs detached from electro-textile antennas during washing: Inside thermoplastic elastomer platform (top) and inside encapsulant platform (bottom).

Based on these preliminary results, the presence or absence of the base layer does not seem to be a determining factor for the glove performance or reliability. Although both coatings have been found to be suitable for protecting textile RFID tags from moisture, the main reliability challenge is found to be the fragile antenna-IC interconnection. As shown in Fig. 7, it appears that the mechanical stresses caused by the washing machine result as detachment of the RFID IC copper pads from the electro-textile antenna patterns. These preliminary results determine the future direction of the research: The next step is to study suitable methods to strengthen the interconnections, in order to these glove-tags to survive the harsh environment inside a washing machine.

V. Conclusions

In this study, washing durability of working glove-integrated passive RFID tags was studied. These glove-tags were embedded inside 3D-printed thermoplastic elastomer platforms and washed 5 times in a washing machine. The results were compared to platforms embedded inside brush-painted stretchable encapsulants. Although both platforms can protect textile RFID tags from the effects of water, the main reliability challenge was again found to be the fragile antenna-IC attachments. Thus, even the thick working glove fabric does not provide enough mechanical support. In order to improve the reliability of the tags, methods to protect the tag antenna-RFID IC interconnection are needed. We will be experimenting and analyzing for example different types of mechanically stronger conductive adhesives for IC attachment. Also, we will be testing embroidery with conductive thread [15] for attaching the RFID IC into the glove-tag antenna. Further, we will be prototyping different

3D printing parameters with NinjaFlex material, in order to strengthen the platform around the RFID IC component.

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