Experimental investigation of washing effects on the properties of textile electrodes

Elena Hadzhigenova[1)], Georgi Nikolov[1)], Elitsa Gieva[2)] and Ivo Iliev[1)]

[1)] Department of Electronics,
[2)] Department of Microelectronics,
Technical University of Sofia, Sofia, Bulgaria,
e-mail: gieva@ecad.tu-sofia.bg

Abstract: *The study represents the results of experimental researche aimed at capturing the frequency characteristics of textile electrodes up to 20 kHz while considering their application in recording of biomedical signals. Two textile electrode models have been examined after a number of washing cycles according to the requirements of standartized procedures ISO 6330: 2012 and ISO 105-C06: 2010 for testing textile products.*

Keywords: textile electrodes, wearable sensors, remote patient monitoring

1. INTRODUCTION

The development and implementation of new materials, the renewal of the element base and new technological solutions related to communication methods and devices create new opportunities for. refinement of the diagnostic process. This specially affects long-term (outpatient) patient monitoring systems.

The aim is to make diagnostics with minimal restriction to the daily activity and comfort of patients, in term of maintaining the quality of the registered biomedical signals [1 - 2].

New trends in the field of long-term medical monitoring comprehend the inclusion of intelligent textile systems designed to capture bio-tension [3 - 7].

Textile electrodes are designed for incorporation into wearable medical systems for the continuous recording, storage and interpretation of biomedical signals, due to their advantages:

- Easy to manufacture and implement;
- Inexpensive;
- Lightweight;
- Do not cause skin irritation and allergic reactions;
- Do not create discomfort for patients;

As an essential element of intelligent textile systems for biomedical signals recording, the electrodes that have direct contact with the body must meet a number of requirements. Most important of which is not interfere with the registered signal during recording. Unlike traditionally used metal electrodes, textiles are subjected to a number of additional effects during the operation of the product in which they are implemented (washing, drying, electrolyte). This requires a number of studies to determine their suitability for use in different situations. [8-10].

This article presents the results of a study on the impact of a series of washing cycles with detergents applied sequentially on two textile electrode models, in accordance with the requirements of the prescriptions of standardized procedures. ISO 6330:2012 and ISO 105-C06: 2010 for testing of textile products.

2. MATERIALS

Two models of textile electrodes were studied:

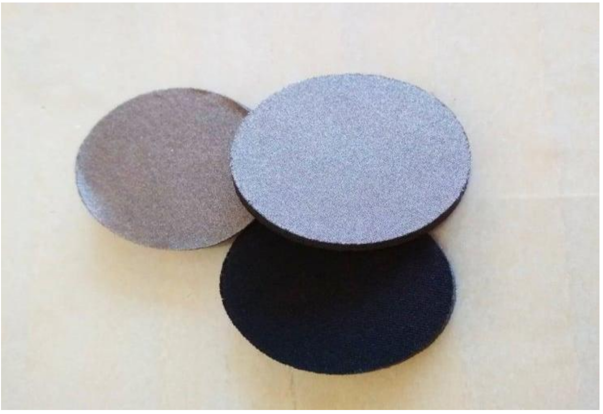

Fig. 1. Textile Electrode – Model 1 – without edge

Model 1 – Electrode without edge - 4 mm thick circular disc; diameter of 45 mm; material - polyurethane foam; contact surface is covered unilaterally with a conductive fabric filled with silver threads.

Model 2 - Electrode with an edge: thickness 30 mm; diameter 45 mm; one side - covered with a conductive fabric (silver threads); another side - covered with rubberized fabric, leaving a cable opening in its central part.

Fig. 2. Textile Electrode – Model 2 – with edge

Among the significant operational factors affecting the quality of registered bio-potentials, serious attention should be paid to:

- treatment of electrodes with detergents;

- the interaction of the chemical composition of the detergents with the contact surface of the electrode;

- the influence of the mechanical damages caused by the deformations accompanying the series of washing cycles on the impedance of the electrodes.

Any change in impedance will directly affect the parameters of the registered biomedical signals. This requires a preliminary assessment of stability of the textile system on a number of treatment (laundry) procedures.

3. MEASUREMENT METHODS

For testing the impedance of conductive textile samples (Models 1 and 2) in the frequency domain, the experimental setup of Figure 3 based on an impedance meter LCR Bridge/Meter HM 8118 (Rohde & Schwarz). This device uses an auto-balanced bridge method to measure impedance Z and the angle between the voltage and the electric current. All other quantities (L-Q, L-R, C-D, C-R, R-Q, Y-Θ, R-X, G-B) are determined mathematically by the instrument. HM 8118 works in the frequency range of DC to 200 kHz, and the effective value of the stimulating sinusoidal signal for the sample used is 1Vrms. The basic accuracy of the device in this case is ±(0,1% + 1 mΩ). HM 8118 connects to a computer via the USB serial interface. It was managed by specially developed code in the LabVIEW area.

4. EXPERIMENTAL RESULTS

The results of the experimental studies with and without edges are presented in graphical form (Figures 4 and 5). With regard to the influence of the number of flushes on the frequency characteristics of the selected textile electrodes, it is found that:

- as the number of rinsed cycles increases, the impedance of the electrodes also increases, which is due to the ongoing reactions with the substances of the detergents, as well as to the corrosion processes leading to the deterioration of the contact resistance.

- the impedance remains relatively constant (after a certain number of flushes), in the frequency range up to approx. 5 kHz. At higher frequencies, after rinsing, there is an increase in the influence of the capacitive component, resulting in a decrease in impedance.

- there is a difference in the behavior of the two types of electrodes after the 20th washing cycle. Edge electrodes largely retain performance, while edges without electrode undergo a more significant increase in impedance values.

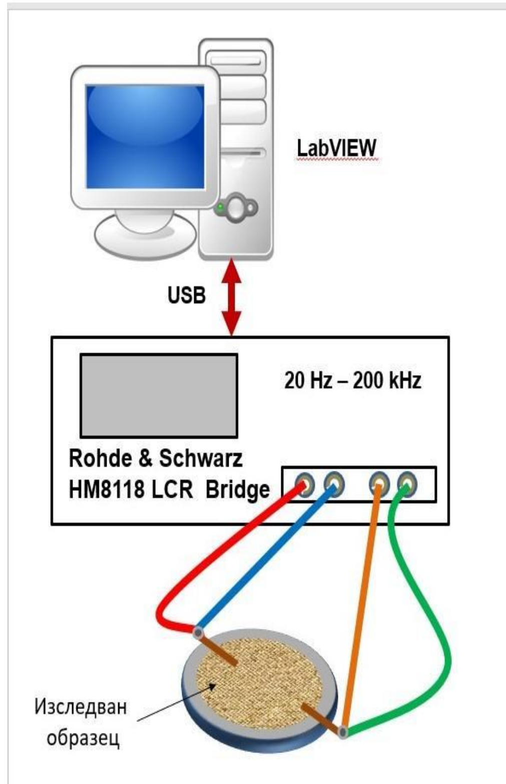

Fig. 3. Scheme of the experimental production

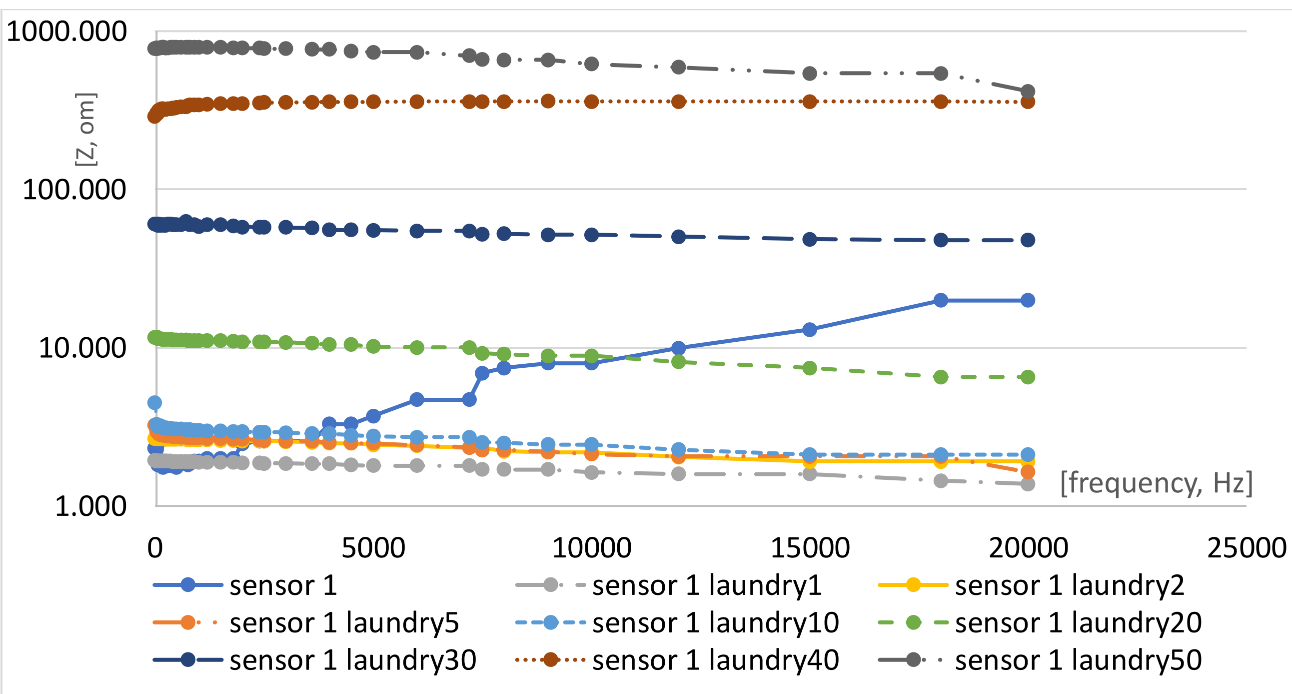

Fig.4: Dependence between impedance and frequency for electrodes without edges after a cycle of 1 to 50 flushes

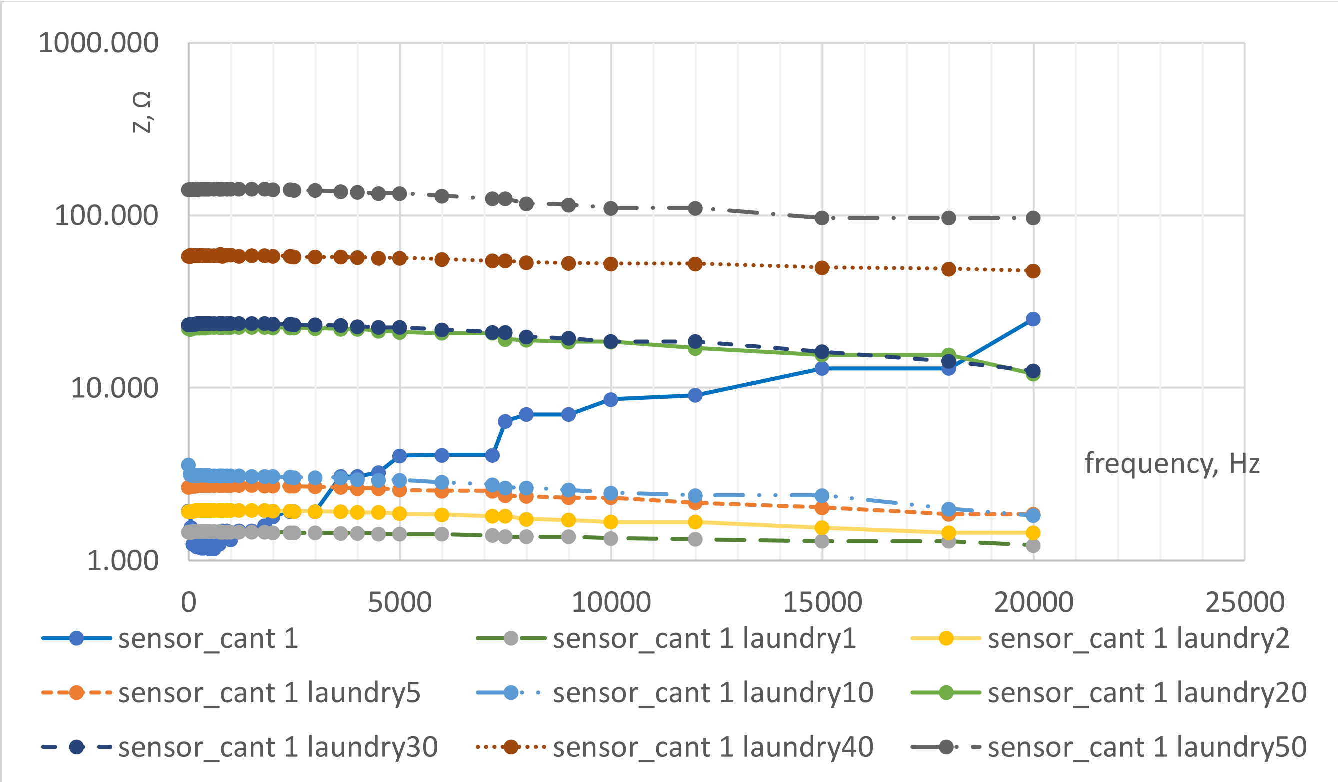

Fig.5: Dependence between impedance and frequency for edged electrodes after a cycle of 1 to 50 flushes

As part of the experimental studies, a structural analysis of the conductive tissues, following the respective wash cycles, was also performed by electron microscope imaging.

On Figure. 6 are enlarged pictures of textile electrodes without edges, and on Figure. 7 with edges respectively with an optical magnification of 500 times. In these pictures, the electrodes are still untreated with washing and chemical reagents.

Fig. 6 Textile electrodes without edge optical representation

Fig. 7 Textile electrodes with edge optical representation

On Figure 8 is illustrated by photos with optical magnification 500 times, a fragment of corrosive violation of the surface of the conductive fiber at an electrode without edges.

Fig. 8 Textile electrode without edge optical representation after the 20th wash cycle

Figure 9 illustrates the surface of an edgeless electrode after the 50th washing cycle, focusing on a fragment with mechanical damage to the conductive filament-forming its surface contact layer. The photos are zoomed 100, 200 and 500 times respectively.

Fig. 9 Textile electrodes without edge optical representation after the 50th wash cycle

The surface of the edging electrodes after the 20th wash cycle is shown by photography with an optical magnification of 500 times Figure. 10. The presence of microcracks on the fibres is clearly visible when compared to the photographs of the respective electrode type, from Figure. 7 before its treatment.

Figure 11 illustrates the surface of an edge electrode after the 50th wash cycle, the focus is placed on a fragment with mechanical damage to the upper layer of the conductive filament forming the contact surface of the electrode. The photos are zoomed 100, 200 and 500 times respectively

Fig. 10 Textile electrodes with edge optical representation after the 20th wash cycle

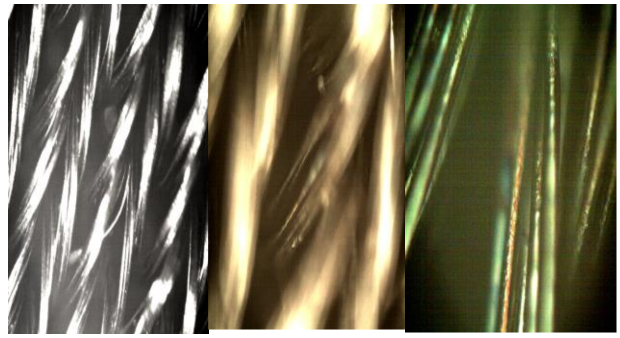

Fig. 11 Textile electrodes with edge optical representation after the 50th wash cycle

5. DISCUSSION

Mechanical separation of the conductive layer of the electrode due to the leaching procedures is also observed in the electrodes without edges. This requires that additional steps be taken during the installation to preserve the integrity of the intelligent textile system.

Mechanical tissue damage, expressed in violation of the integrity of the fibers forming the conductive part of the electrodes, is also an important element. These damages are due to microfractures occurring, from which a conductive fabric is made, covering the contact surface of the electrode and coming into direct contact with the patient's body. In turn, micro-breaks lead to the presence of many new contact points, which leads to an increase in the resistance of the electrodes.

In contrast to the non-edge electrodes, the edge impedances show a retention of the impedance values obtained after the 20th and 30th washing cycles and a much less pronounced increase after the 50th washing cycle. The resulting micro-fractures of the fibres in this case are much lower.

6 CONCLUSIONS

As a result of the experiment, it is concluded that the electrodes filled with edging are much more protected from the harmful mechanical effects of the washing procedures. In the case of electrodes with the edges, the degree of deformation of the conductive layer made of silver metal filaments is significantly lower, which affects the reported impedance values, respectively, on the properties of the measured signals.. The effect of corrosion on the f ibres forming the conductive layer as well as that of the detergents on the quality parameters of the conductive tissue from which the f ibres are made is much lower than that of the electrodes without edges..

Changes in the parameters of the textile electrodes for both samples would not significantly affect the quality of the registered biomedical signals, but it would be appropriate to provide for self-calibration options so as to completely eliminate the effect of washing on the quality of the recorded signals.

6. ACKNOWLEDGEMENT

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