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FLEXIBLE MATERIAL FOR WEARABLE ECG ELECTRODES

Raluca Maria AILENI[1], Laurentiu DINCA[2], Sever PASCA[3], Rodica STRUNGARU[4]

This paper presents a flexible electrode obtained on a textile structure made from conductive yarns and used for biomedical monitoring applications based on ECG. The knitting technology was used for obtaining the electrode based on polyamide monofilaments coated with silver [1]. These dry electrodes have applicability for wearable heart rate monitoring systems because does not require using the gels and will be wearing on the body. The treatment of the monofilaments with silver has the goal of obtaining the medical electrode Ag based and antimicrobial properties for material that will be in contact with the human body skin [1]. The silver monofilaments coating performance was analyzed by energy dispersive X-ray spectroscopy (EDX), and by using the scanning electron microscope attached to EDX system.

Keywords: ECG, electrodes, wearable, metallic, conductive, monitoring, medical

1. Introduction

Wearable technology means body worn electronics, by using invasive method (implants) or noninvasive (external accessories). Both invasive and noninvasive wearable have in common some characteristics such as mobility, autonomy and wireless connection, that allow data exchange, records and data analyze through software applications (IoT). The digital revolution and mobile networks development had a crucial role in the development of wearable technology. There are wearable devices for heart rate activity, such as pulse monitoring systems or ECG systems, developed by using wet methods based on electrolytes and electrodes or dry methods without using of electrolytes. The actions potentials produced by all heart muscle fibers during a heartbeat generates electrical currents – signals that can be monitored at the surface of the body by using electrocardiograph device and recorded in ECG. The electrodes positions,

[1] PhD Student, Dept. of Applied Electronic and Information Engineering, University POLITEHNICA of Bucharest, Romania, e-mail: raluca.maria.aileni@gmail.com
[2] Scientific Researcher, INCDTP, Romania
[3] Prof., Dept. of Applied Electronic and Information Engineering, University POLITEHNICA of Bucharest, Romania
[4] Prof., Dept. of Applied Electronic and Information Engineering, University POLITEHNICA of Bucharest, Romania

for clinical use, are on the arms or legs and at six positions on chest in order to record the ECG [2].

Standard commercial Ag/AgCl electrode, used for ECG signal monitoring, contains conductive gel for a good electrical conductivity when the electrodes are in contact with human skin. The human skin (Fig. 1) structure includes vascular network, nervous components and sweat glands that can influence the human skin conductivity by moisture and temperature (that is also proportional to blood flow rate and the difference between the body core temperature and local tissue temperature). If the skin' level moisture level is higher than normal moisture average, then the electrodes will become wet and will lead to signal errors. The conductive gel often dries in time and this lead to impedance variations and a signal quality reduction.

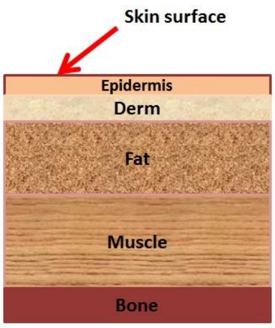


Fig. 1. Human skin

For ECG monitoring are used autonomous devices with electrodes, electrodes integrated in cloths or wearable patch platforms.

The wet electrodes technology can be replaced by an active electrods that can be dry electrodes (metallic surface in contact with human body skin and uses a combination of resistive and capacitive coupling to the local skin potential) or insulated electrodes (use only capacitive coupling to local skin potential) [3, 4].

In this paper, we present the flexible dry electrode developed for wearable ECG, the laboratory tests performed and the ECG wireless monitoring system proposed.

2. Related Work

An ECG system worn on the body is a wearable device. A wearable wireless patch for healthcare monitoring is a platform used for heart rate, respiration rhythm, ECG, glucose and activity monitoring (NXP). Wearable patch lead to increase patient mobility and comfort and can wirelessly upload vital signs data to the cloud for real- time analysis and permanent data record [5, 6].

A wearable wireless platform developed at Northwestern University [7], with integrated electronics for sweat analysis, allows patients health monitoring without blood sampling (Fig. 2).

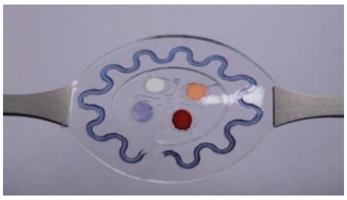


Fig. 2. Flexible wearable microfluidics device for sweat monitoring

The microfluidic fabrication techniques can be oriented in fabrication of the flexible microfluidic wearable structures with electrically conductive elements embedded on soft, flexible and stretchable materials. These flexible microfluidic wearable technologies are useful for biomedical sensing applications, such as in situ sweat metabolites analysis, vital signs monitoring, and gait analysis. The future wearable microfluidics patches will perform the active drug delivery, soft robotics sensing and control, and even implantable artificial organs.

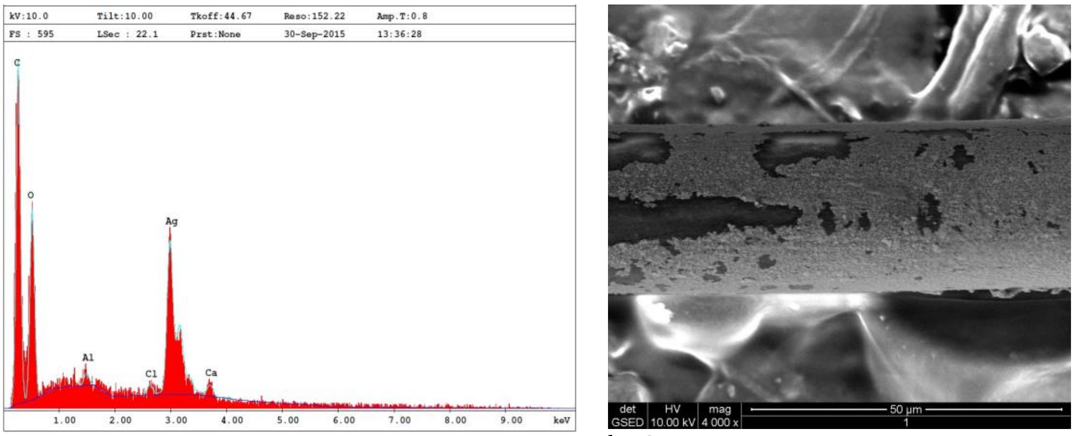
The integrating of electronics part or use of electrodes integrated in cloth was and is a challenge for many researchers. By collaboration between hWear HealthWatch Ltd. (Israel) and MedTech Edge (Australia) was developed hWear - a revolutionary digital, heart-sensing garment incorporating interwoven textile electrodes [8] for heart continuous monitoring by 15-lead ECGs (Fig. 3).

Fig. 3. hWear –ECG monitoring [5]

3. Experimental Part

We developed flexible electrodes by textile structure made from conductive yarns. These electrodes are applicable for biomedical noninvasive monitoring applications based on ECG. For signal acquisition, we used an ARDUINO shield and a Bluetooth device for wireless communication. In this work is presented the dry flexible metallic electrode developed by knitting technology and is based on polyamide monofilaments coated with silver [1]. The treatment of the monofilaments with silver has the goal of obtaining the medical electrode Ag based and antimicrobial properties for material that will be in contact with the human body skin [1]. Also, due to elastic properties of the knitted electro-conductive structure that is in a good contact with skin it is not required to use conductive gel for signal monitoring ECG.

For highlighting the silver coating performance, the monofilaments were analyzed by energy dispersive X-ray spectroscopy (EDX), microanalysis (EDAX –Fig. 4.a) and by the scanning electron microscope (SEM –Fig. 4.b) attached to EDX system. A 10kV electron beam performed the analysis, for this electrode, with 10 mm working distance and 10 degrees tilt. The EDX results ‘quantification was made by the standard EDAX ZAF quantification method [3].



a. EDAX b . SEM

Fig. 4. EDAX and SEM analyses for conductive monofilaments used for electrodes

The classical electrode structure can be reduced by flexible electrodes and removing the necessity of using the gel (Fig. 5).

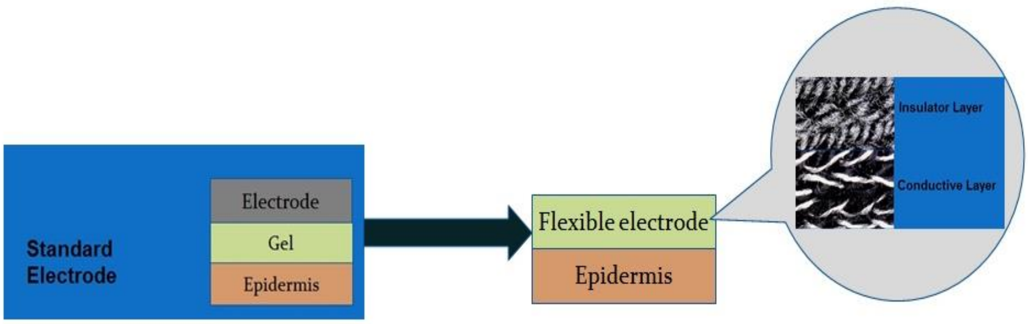


Fig. 5. Standard electrode vs. flexible electrode

For ECG system based on flexible electrodes (Fig. 6), we propose a smart wireless system based on flexible analogic part (conductive sensitive electrodes), signal conditioning, A/D converter, wireless module and aggregator (PC, Notebook of smartphone).

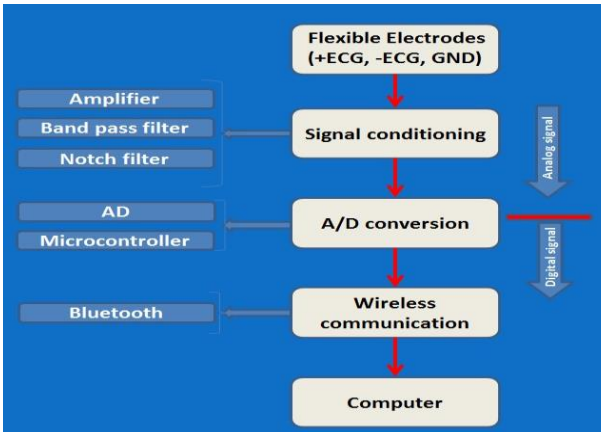


Fig. 6. Wireless ECG monitoring system

In the laboratory, for measure the surface resistance of the flexible electrodes we used the devices: PRS-802 Resistance system measure, PTB-920 Concentric Ring, PRF-911 Concentric Ring and a weight 5lb (Fig. 7). The knowledge about surface resistance and conductivity it helps in defining the optimal surface for flexible electrodes. We conducted laboratory tests for measure the surface resistance for the following surfaces:

➔Conductive knitted electrode surface and the results obtained are 18.5 Ω for material back side and 9.5 Ω for material front side (Fig. 7);

➔Skin surface on hand and the results obtained are $1.6\,x10^{5}$ Ω for hand front side and $1.25x10^{13}$ Ω for hand backside.

➔Insulator material and the result obtained are $9.3x10^{12}$ Ω for backside and $2x10^{13}$ Ω for front side.

a. Devices b. Electrode measurement

Fig. 7. Surface resistance measurement

4. Conclusions

The interest in wearable technologies arises from control and monitoring need in medical or fitness area. Even if the integrating of the microfluidics lab-on chip in wearable technologies has a high potential, for healthcare applications (monitoring, bio and chemical analysis), the integration of flexible electrodes obtained by mechanic-textile processes is more accessible for developing and integration.

The flexible electrodes based on conductive threads for ECG monitoring have the advantages:

- The electrode is flexible due the knitted structure;
- The electrode is wearable and can be integrated in clothing articles;
- Autonomous system by using in personal health monitoring (telemedicine);
- The flexible dry electrode eliminates the necessity of use the gels required by classical electrodes.

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