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# Novel Skin-Electrode Conductive Adhesives to Improve the Quality of Recorded Body Signals in Smart Medical Garments <sup>†</sup>

Azadeh Soroudi <sup>1,\*</sup>, Mikael Skrifvars <sup>2</sup> and Vincent Nierstrasz <sup>1</sup>

<sup>1</sup> Department of Textile Technology, Faculty of Textiles, Engineering and Business, University of Borås, 501 90 Borås, Sweden; vincent.nierstrasz@hb.se

<sup>2</sup> Swedish Centre for Resource Recovery, Faculty of Textiles, Engineering and Business, University of Borås, 501 90 Borås, Sweden; mikael.skrifvars@hb.se

\* Correspondence: azadeh.soroudi@hb.se

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**Abstract:** A main barrier to widespread use of electrocardiography garments for long term heart monitoring of elderly and patients is a poor skin-electrode signal transfer because of a high contact impedance and sensitivity to movement. This leads to unwanted disturbances and errors in recorded signals when the patient moves or even breathe, affecting the reliability and quality of the signals especially for patients with dry/old skin. In two different projects at the University of Borås, we have developed two novel products to solve the above problem; (1) an ongoing project that has fabricated a reusable and sustainable electro-conductive adhesive applicable between the skin and high-porous textile electrodes, and (2) a patent-pending skin-electrode glue (BioEl Glue<sup>®</sup>) which is a biocompatible electro-conductive water-soluble glue used between skin and low-porous textile electrodes.

**Keywords:** contact impedance; skin electrode interface; textile electrodes; ECG garments; medical garments; electrocardiography garments; smart textile; wearable electronics; wearable ECG

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## 1. Introduction

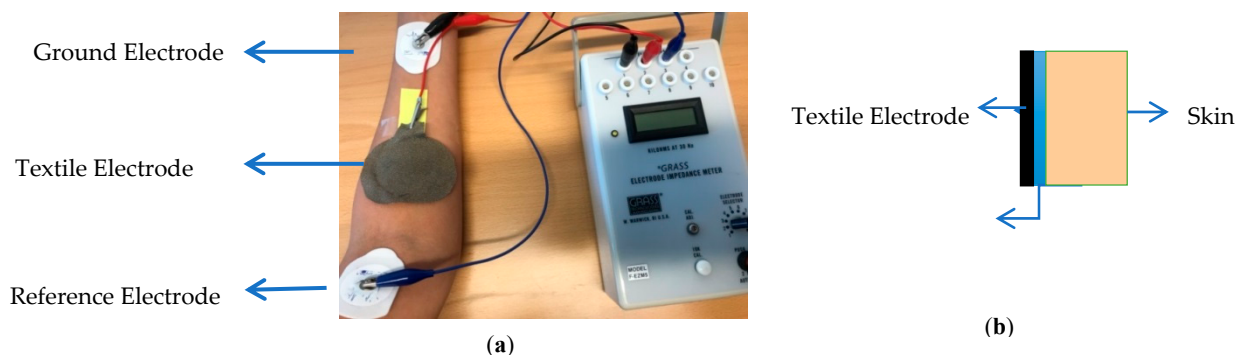
Wearable health monitoring garments can reduce hospital costs and increase life standards, thus contribute to sustainability. However, the main challenges limiting the commercialisation of wearable monitoring systems such as ECG (electrocardiography) garments are the improper electrode-skin interface and motion artefact, affecting the reliability and quality of the bio-signals [1–3]. Although humidity [4] and increased pressure on textile electrodes [5–8] can improve the quality of recorded signal, however dry/old skin cannot create enough humidity, and even if water is added to the electrode, it will evaporate after a few hours resulting in noises. Furthermore, constantly applying water is inconvenient for long-term monitoring. On the other hand, although pressure can improve skin-electrode contact and also reduce motion artefacts, however can create discomfort for the wearer especially under long-term monitoring.

We have developed two different products within two different projects at the University of Borås to solve the above problem; (1) an ongoing project which has fabricated a reusable and sustainable electro-conductive adhesive to be used between skin and high-porous textile electrodes; and (2) a previous project which has developed a skin-electrode glue [9], BioEl Glue<sup>®</sup>, that is a biocompatible electro-conductive water soluble glue used between skin and low-porous textile electrodes. The prepared adhesive and glue have been characterised regarding electrode-skin contact impedance, ECG signal recording and skin reaction after different periods of exposure.

## 2. Materials and Methods

To perform the projects, proper and safe polymers, electro-conductive particles and additives are blended together using IKA-mixer, and under selected processing conditions so that a homogeneous electro-conductive mixture with good adhesion properties to both the skin and the textile electrodes is achieved. Both reusable conductive adhesive, and water-soluble conductive glue, have been formulated to be biocompatible, anti-irritation and non-diffusible through the targeted textile electrode over a long period of time.

Skin-electrode contact impedance was measured by the three-electrode method on hand as shown in Figure 1a, and using Grass impedance meter F-EZM5, as described in details in our previous publication [10]. ECG signals were also recorded with the method previously reported [10].



**Figure 1.** (a) Skin-electrode contact impedance measurement, using three electrodes on hand. (b) The schematic of using conductive adhesive/glue between the skin and electrode.

## 3. Results and Discussions

Both developed electro-conductive adhesive and glue have been applied between skin and textile electrode to act as an active interface between two surfaces as shown in Figure 1b.

### 3.1. Reusable Conductive Adhesive

A reusable electro-conductive adhesive is developed with the aim to be used between skin and high-porous textile electrodes. To predict the performance of the electrode adhesive in ECG garments for long-term monitoring, the skin-electrode contact impedance, skin irritation and both functionalities up to three days are studied so far.

Measuring the skin-electrode contact impedance is a method to give valuable information about the quality of signal transfer between skin and the electrode; low skin-electrode impedance shows a good skin-electrode interface, thus good quality bio-signals can be recorded, while high impedance means high distortion and noises in recorded signals; furthermore, continuous measurement of electrode impedance can be used for the estimation of motion artefacts [11–13].

Table 1 presents the measured skin-electrode contact impedance for textile electrode with/without applied pressure as well as with/without using adhesive as the middle layer. A clear observation is that adding a layer of developed conductive adhesive between skin and the electrode has greatly decreased the contact impedance, which is an indication of the ability to deliver higher quality ECG signal recording, furthermore, it is comparable with our previous product, BioEl Glue® [9]. The decreased contact impedance when using the reusable conductive adhesive is even more than applying 28 mmHg pressure on the textile electrode for promoting better contact; furthermore, 28 mmHg pressure is not comfortable for the wearer specially under a long-term measurement. The prolonged contact impedance measurement up to 72 h, adhesion to the skin and skin reactions in contact with the adhesive under the same period of time are presented in Table 2, all showing desired results.

**Table 1.** Measuring the contact impedance between textile electrode (Shieldex) and skin with and without applying pressure, as well as with and without using conductive adhesive/glue.

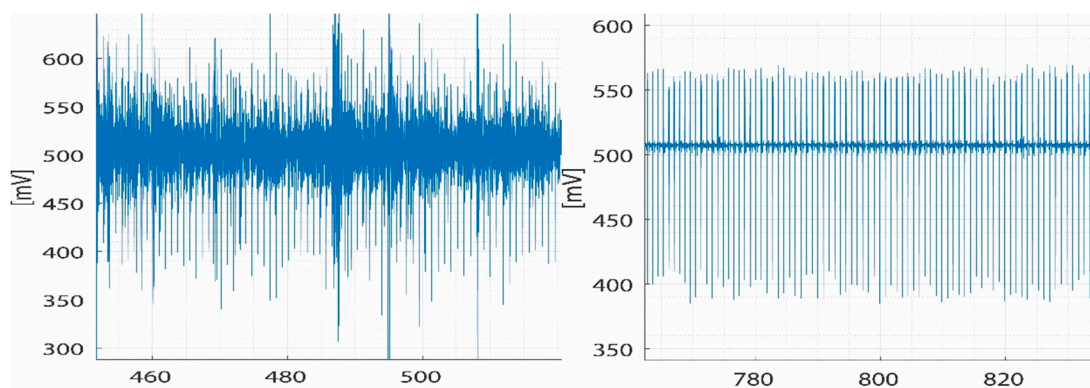
Test Condition	Pressure, mmHg	Contact Impedance, kΩ
Textile electrode/skin	0	>200 thus not measurable
Textile electrode/skin	28	164
Textile electrode/conductive adhesive/skin	0	75
Textile electrode/BioEl Glue®/skin	0	65

**Table 2.** Measuring the contact impedance for reusable conductive skin adhesive when used between skin and electrode up to 3 days.

Duration; Adhesive on Skin	Adhesion	Skin Irritation	Itchy	Contact Impedance, kΩ
0 h	Good	-	-	101
24 h	Good	No	No	95
48 h	Good	No	No	85
72 h	Good	No	No	82

### 3.2. Water Soluble Conductive Skin Glue

During our previous project, we have developed a patent-pending product [9], BioEl Glue®, which is a non-drying, anti-irritation, electro-conductive and biocompatible glue-like paste, used between low porous textile electrode and the skin. The ability of this electrode glue to decrease the skin-electrode impedance is shown in Table 1. Figure 2 presents how using this glue between the skin and electrode has improved the recorded ECG signal quality through decreasing the amount of noises and motion artefacts in recorded signals in a wearable ECG garment, called WearItMed [10,14].



**Figure 2.** Recorded ECG signals for dry skin; left: textile electrode on skin; right: electro-conductive BioEl Glue® between skin and the same textile electrode. Low pressure of 2 mmHg was applied on electrodes.

## 4. Conclusions

To decrease the motion artefacts and record medical quality signals by wearable ECG garments, applying developed electro-conductive and biocompatible adhesive /glue between the skin and electrodes is a practical, safe, user friendly and low-cost solution.

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