Textile application in bio-potential recording used for medicinal purposes: an overview

Dr. Tasnim N. Shaikh[1], Dr. S. B. Chaudhari[1*], Dr. B. H. Patel[2] and Ms. Megha Patel[1]

[1]Department of textile engineering, faculty of technology & engineering, the maharaja sayajirao university of baroda, vadodara, gujarat, india.

[2]Department of textile chemistry, faculty of technology & engineering, the maharaja sayajirao university of baroda, vadodara, gujarat, india.

Abstract

Bio-potential signals in the form of eeg and ecg are the two critical health indicators that are directly suited for long-term monitoring using bio-sensors. The conventional wet adhesive ag/agcl electrodes are the most commonly and commercially used in clinical applications today for these purposes. They provide an excellent signal but are cumbersome and irritating while operated with gels, adhesives and even causes certain skin problems when come in direct contact with the outer dry layer of skin. Invention of textile electrode is the outcome of the search for suitable option for this classical technique. Various textile structured electrodes developed in the course have shown a bright sign of improvement in work practices. Successful development and commercialization of an interactive textile based bio-potential device can leave a profound influence on health monitoring system in the society. This paper extends platform for the critical theoretical review of overall developments took place in textile structured electrodes used for long term monitoring of cardiac issues.

Keywords: *Electrocardiogram, Bio-Potential Signals, Ag/Agcl Electrodes, Textile Electrodes*

I. Introduction

Bio-potential recordings in the form of electrocardiograms (ecg), electroencephalograms (eeg), electrooculograms (eog) and electromyograms (emg) are indispensable and vital tools for tracking person's health [1]. Commercially available portable bio-signal monitoring device available now days, has given the facility to monitor cardiac patients continuously at any place and situation. Thereby it can be used effectively in telemedicine and home-care scenarios for diseases prevention and management, early diagnosis and home rehabilitation. Electrodes in such system serves as signal acquisition apparatus that creates an electrical interface between the body and the measurement system, allowing the electrical charges to flow through the tissue and to sense the endogenous bio-potential signals [2-3].

An electrode during its development stages has undergone through vast changes. Heart bioelectrical phenomenon and study of ecg was traced back in early 1842, when italian physicist calo matteucci [4] found that an electric current accompanies each heart beat. Richard caton, a liverpool physician was the first to use electrodes in 1875 to detect electroencephalogram by placing electrodes on two points of the external surface, one on gray matter and the other on the surface of the skull. Later, ag/agcl body-surface plate electrodes were used for ecg measurement, with electrolyte between the electrode and skin to improve skin-electrode contact. Success of ag/agcl electrodes over other electrodes made from different materials was mainly attributed to good conductivity of silver and weak polarization of ag/agcl, acquiring high fidelity signals [5]. Such superiority of the ag/agcl electrode still remain unbeaten and been widely used in regular ecg measurement nowadays. But, it is not an ideal electrode, for long-term monitoring, due to dehydration of electrolyte or wet gel, affecting the signal quality [6-7]. Even this gel will cause some skin allergies such as skin irritation, dermal inflammation, and other skin problems [8]. Also, wet gel electrodes adhere to the skin, causing the patient discomfort. Researchers have done intensive efforts to overcome these limitations of classical electrode. Options were tried out in the form of dry electrodes and textile electrodes with vivid structures.

II. Commercial Electrodes

Since the main role of an ecg electrode is to change the voltage from its ionic form in the body to its electron form in the wires, all electrodes are differentiated either as polarizable or non-polarizable, the way they behave during measurement. Most of polarizable electrodes are employed to human skin in dry state and thereby also categorized as dry electrode. Similarly in wet conductive media, gel is compulsorily used between skin and electrode for non polarizable electrode, often referred as wet electrodes [1, 9].

Perfectly polarizable electrodes ideally do not permit any electrode reactions, when a given electrical potential is applied. Therefore, no charge will flow across the electrode-electrolyte interface, and the electrode will behave as a capacitor [9]. Current flowing through a lead with this type of electrode is always a displacement current. In contrast, perfectly non-polarizable electrodes are electrodes that are not polarizable. In this type of electrode, the current flows freely across the electrode without producing any potential, whereas an ideal non-polarizable electrode behaves as a resistor with a nominal resistance value that is ideally to zero. The main non-polarizable electrode is the traditional ag/agcl electrode. In this group of electrodes, an electrochemical process occurs between the gel and the biological tissue which yields a conductive path between the patient's skin and electrode [1, 3, 9, 10], and real electric current flows through this path. These electrodes are superior to other electrodes made from different materials as silver has good conductivity. They are weakly polarized which gives low and stable skin-electrode contact impedance, thus acquiring clean and reliable ecg signals [1, 10, 11].

Further they are categorized as per their design and application mode, viz; suction electrodes, metallic plate type electrode and floating electrode [figure 1 (a-c)]. Suction electrodes consist of a hollow metallic cylinder (electroplate), which is placed in contact with skin at its base and a rubber suction bowl is fitted on its other base [figure 1 (a)]. These electrodes are used with electrolyte gel or conduction gel, applied over the contacting surface of the electrode. Electrodes get fixed at its position with the help of suction bowl. Since low air pressure is the only media to support electrode at its position, such types of electrodes are not ideal for long term monitoring. Whereas metal plate electrodes are modified version of suction electrodes. They are self adhesive and pre-gelled electrodes, where adhesive acts as bonding media between skein and electrode, and gel provides conductive layer [figure 1 (b)].

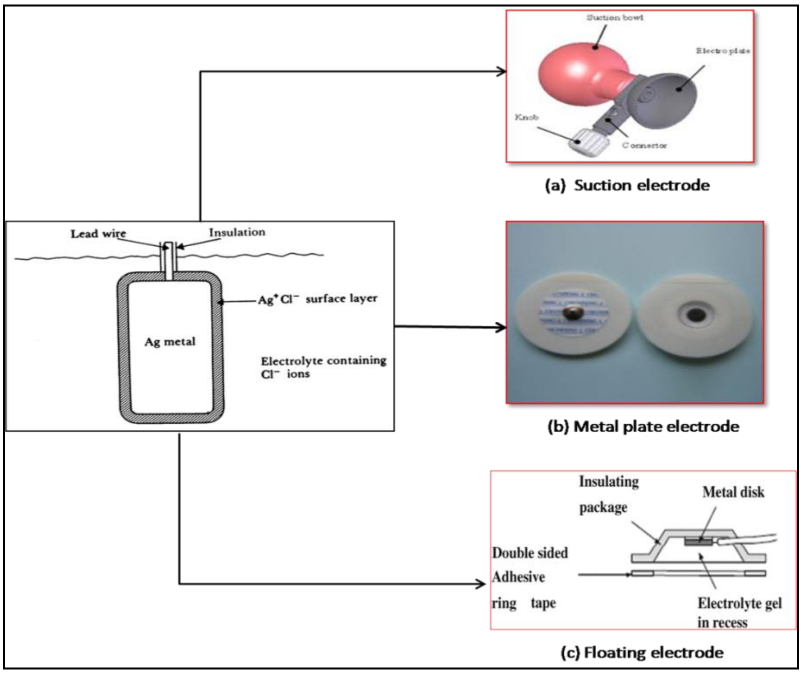

Figure 1 Commercial Electrodes

Since gel is composed of ag/agcl as conductive matter, metal plate electrodes are commercialized as ag/agcl electrodes. These types of electrodes are fixed firmly on skein by adhesive with due pressure for a long interval of time, popularly used for long term ecg, emg or eeg recording. However this adhesive part and gel inside them can cause some skin allergies like skin irritation, dermal inflammation and other skin problems. Also it requires skin preparations in advance, such as shaving and cleaning the contact area [11]. The most significant drawback is that the signal they detect, will get degraded when their inside gel dries (dehydrates) out. Traditional ag/agcl electrodes are not appropriate for long-term monitoring [1, 3]; thereby textile electrodes have recently been enthusiastically investigated as an alternative to traditional one.

III. Textile Electrodes

Textile structural materials as an ecg electrode are fairly a new concept. They are the one composed off textile fibers, yarn or fabric, made conductive by using conductive matter integrated in the structure either by reinforcing or, coating, going to be placed on the skin and connected to a measurement system for recording electrical potential and its variation normally the textile electrodes are made by weaving, knitting or embroidering conductive yarn to the structure [1, 3, 12]. The conductive yarn can be silver coated yarn or metal filaments braided into yarn. The textile materials used as electrodes are usually synthetic for example polyester or polyamide. They endure very well abrasion, absorb a very little moisture and dry fast [13]. A textile electrode must be sufficiently high conductive, comfortable on contact of fabric with skin, should have higher shelf life against washing and should be easily laundered, strong and flexible enough to resist the several actions such as stretching, bending, twisting, rubbing etc. During its use and must be electrochemically stable and mechanically robust [14].

Several authors have reported work on measurement of ecg signals using textile-integrated electrodes. They have adopted different methods and materials to fabricate textile electrode. In early of year 2000, lot of work was done for the production of textile electrodes. Mühlsteff et al [15] had proposed the use of dry rubber electrodes, former had used detachable electrodes made of conductive rubber itself but later one had imparted conductivity to nonconductive rubber electrodes by printing with conductive silver particles. G. Loriga, et al. [16] derived textile sensing cloth, where conducting and piezo resistive materials were integrated in the form of fibers and yarns [figure 2 (a)]. The electrode was knitted with a cotton base textile yarn where a stainless steel wire twisted around it. He developed a multilayered structure conductive surface was sandwiched between two insulated standard textile surfaces. T. Kannaian, et al [17] in their work, have designed and developed textile electrodes by embroidering silver-coated nylon thread (conductive yarn) on 100% polyester fabric with satin stitches to measure electrocardiogram bio-signals of patients [figure 2 (b)].

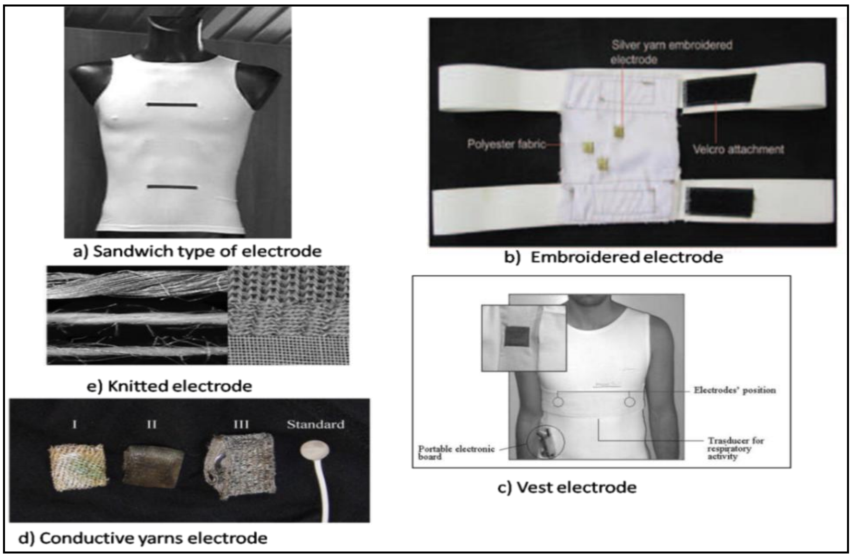

Figure 2 Textile Electrodes

Linda rattfalt et al [18] developed the electrode using three different conductive yarns; consisted of multi filaments of 100% stainless steel plain knitted, 20% ss and 80% polyester spun mixture of short staple fibers with a wave knitted corrugated structure and a core of polyester fibers with a mono-filament of silver platted copper twined around it [figure 2 (e-d)]. The improvement in conductivity of textile material has also tried with nano silica on cotton and polyester fabrics by b. H. Patel et al and s. S. Bhattahcharya et al [19, 20]. Likewise t.n shaikh et al [21] in their work have developed a nonwoven polypropylene based electrode loaded with copper nano particles. Jang, s., et al. [22] used copper sputtering surface of the fabric and had produced a conductive fabric electrode. Xu jie, li meixia [23] used electro less nickel plating on the fabric substrate which was coated with a layer of metallic nickel on the surface of a conductive polymer, possessing a catalytic activity of making fabric electrodes.

Further development took place with the wearable devices which allow people to monitor their fitness and health without causing any interruption. Wearable devices are washable and the sensors are embedded into the garment to collect and continuous monitoring of physiological signals. The acquired data of the wearer is then transmitted to wireless module [24]. Below are examples of such wearable devices.

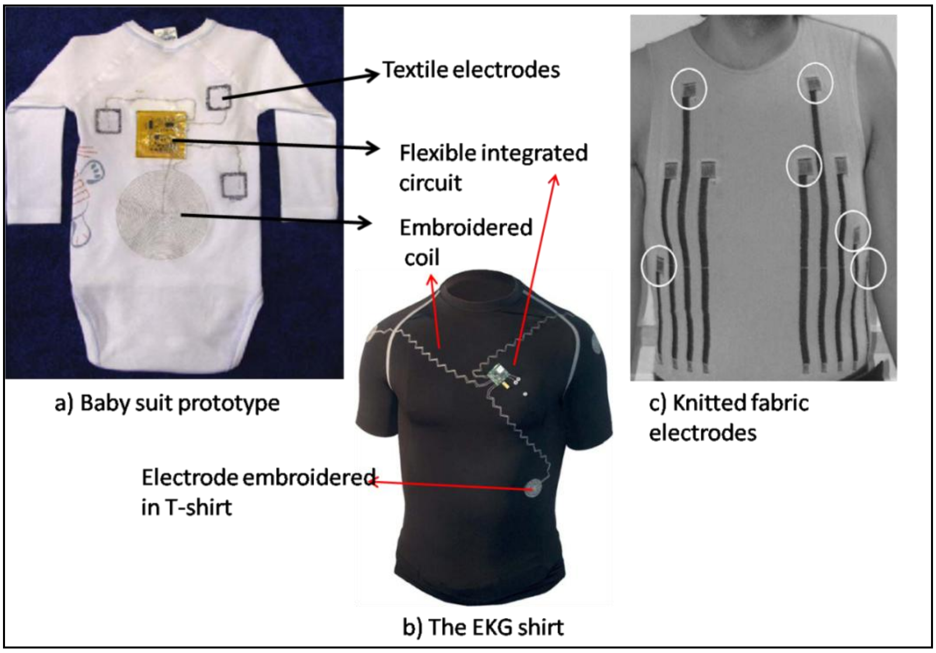

Figure 3 Wearable Health Care System

J. Coosemans et al [25] developed the system for continuous monitoring of the electrocardiogram (ecg) of children with an increased risk of sudden infant death syndrome (sids) [figure 3(a)]. The sensors and the antenna were made out of textile materials. All electronics were mounted on a flexible circuit, fabricated in a baby suit prototype. Torsten linz et al [26] developed an ekg shirt [figure 3(b)] which measures the signals using an interconnection based on embroidery of conductive yarn. R. Paradiso et al [27] developed a wearable health care system (wealthy) with a conductive yarn knitted fabric sensor, which showed a comparable signal to standard sensors [figure 3(c)].

3.1 Problems Associated With Textile Electrodes

Broadly speaking, textile electrode is the one having combination of dry and non-polarized electrodes of the traditional practices. Differing from classical trend they are wearable electrodes either inbuilt into clothing or applied with the help of pressure bandages [5-6]. Unlike regular ecg electrodes, textile electrodes do not require any gel application in order to achieve desired contact with the skin, thereby categorized as dry electrode comfortably. Even elimination of wet gel also facilitates in getting rid of gel associated skin problems [1, 9, 10]. Moreover these electrodes are flexible and stretchable, which can fit well to the skin contour, thus improving skin electrode contact. They can be used comfortably for long term monitoring and having good washing resistance [1]. However, they suffer from two major draw backs viz; higher cost of material and manufacturing, since electrodes are made using stainless steel yarns having diameter > 30 microns are uncomfortable to skin due to added stiffness of conductive yarn [1, 3, 18] and also the contact resistance between skin and dry electrode has not been achieved from previous works causing motion artifacts in the signals.

IV. Conclusion

ECG is the most frequently used medical diagnosis tool for patients with heart diseases. Ag and agcl combinations are considered to be the optimum materials for ECG electrodes as the low and stable over potential, which directly determines the motion artifacts. Currently commercial type electrodes are metal plate electrodes, metal plate floating electrodes in a gel, flexible carbon, or silicon with a layer of gel. Compared to the conventional ag/agcl electrode, textile electrodes have their superiorities. They are easy to integrate into clothes making them wearable, unobtrusive and providing easy access to mobile health care. They are assumed to be a potential alternative electrode in long-term health monitoring.

However, due to the flexible structure, it easily moves against the skin, introducing much more noise. Most textile electrodes are metal coated, but in long-term monitoring, surface degradation, coating durability, and electric performance variations are also being faced by the researchers. Moreover, electrode electromagnetic shield and lead wire connection is still uncertain. However further research has to be performed to ensure a good contact resistance with the skin to achieve high fidelity signals without causing motion artifacts. Design of electrodes and choice of material still can be improved to achieve wearable and comfortable smart ware fabric electrodes for clinical purposes.

References

[1] P.j. xu, h. Zhang and x.m. tao, "textile-structured electrodes for electrocardiogram", textile progress, vol. 40, no. 4, pp. 183–213, 2008.

[2] P. Ask, p. A. Oueros, t. N. Odxia, tenlanan and m. Skoch, "egg electrodes -a study of electrical and mechanical long-term properties by acta atiaesth. Scand., vol. 23, pp. 189-206, 1979.

[3] N muthu kumar & g. Thilagavathi, "textile electrodes for ecg and eeg monitoring", journal of technical textile, vol. 74, no. 2, pp. 81-86, 2013.

[4] C. Zywietz, a brief history of electrocardiography-progress through technology, 2003.

[5] R. Caton, adolf beck, "a pioneer in electroencephalography in between richard caton and hans berger", br. Med. J., vol. 9, no. 4, 216–221, 2013.

[6] J.y. baek, j.h. an, j.m. choi, k.s. park, and s.h. lee, "sensors and actuators a-physical", vol. 143, pp. 423-429, 2008.

[7] Http://en.wikipedia.org/wiki/electrocardiography, referred on 1st may 2015.

[8] Patent us5178143a-electrically conductive gel composition, jan 12, 1993.

[9] T. Bahareh, s. Shervin, "impact of skin–electrode interface on electrocardiogram measurements using conductive textile electrodes senior member", ieee, voicu groza, fellow, ieee.

[10] J. Carlos and m. Ruiz, "on the feasibility of using textile electrodes for electrical bio-impedance measurements stockholm", sweden, february 2011.

[11] Patent us3901218-disposable electrode, oct. 26, 1973.

[12] J. Lofuede, f. Seoane and m. Thordstein, "soft textile electrodes for eeg monitoring" ieee, 2010.

[13] L. Rattfält, "smartware electrodes for ecg measurements-design, evaluation and signal processing", department of biomedical engineering, sweden, october 2013.

[14] M. Neruda, and l. Vojtech., "verification of surface conductance model of textile materials", journal of applied research and technology, vol. 10, no. 4, pp. 579-585, 2012.

[15] Y. Zhai, x. Liu, y. Wang, x. Li, "progress in preparation and application of fabric electrodes" journal of minerals and materials characterization and engineering, vol. 2, pp. 598-604, 2014.

[16] G. Loriga , n. Taccini, d. De rossi and r. Paradiso, "textile sensing interfaces for cardiopulmonary signs monitoring", engineering in medicine and biology 27th annual conference shanghai, china, september 1-4, 2005.

[17] T. Kannaian1, r. Neelaveni and g. Thilagavathi, "design and development of embroidered textile electrodes for continuous measurement of electrocardiogram signals", journal of industrial textiles, vol. 42, no. 3, pp. 303–318, 2012.

[18] L. Rattfalt., m. Linden, p. Hult, l. Berglin and p. Ask, "electrical characteristics of conductive yarns and textile electrodes for medical applications", med biol eng comput, vol. 45, 1251-1257, 2007.

[19] S. S. Bhattacharya and s. B. Chaudhari, "study on structural, mechanical and functional properties of polyester silica nanocomposite fabric", international journal of pure and applied sciences and technology, vol. 21, no. 1, pp. 43-52, 2014.

[20] B. H. Patel, s. B. Chaudhari, a. A. Mandot, c. J. Panchal, "silica particles can improve electrical conductivity of polyester and cotton", textile asia, vol. 46, no. 3, pp. 39-41, 2015.

[21] T. N. Shaikh, s. B. Chaudhari, b. H. Patel and m. Patel, "study of conductivity behavior of nano copper loaded nonwoven polypropylene based textile electrode for ecg", international journal of emerging science and engineering (ijese), vol. 3, no. 4, pp. 11-14, 2015.

[22] S. Jang, et al., "exploring possibilities of ecg electrodes for bio-monitoring smartwear with cu sputtered fabrics human-computer interaction", interaction platforms and techniques, 4551, pp. 1130-1137, 2007, http://dx.doi.org/10.1007/978-3-540-73107-8_124.

[23] J. Xu, "a method for preparing the dye-sensitized solar cell fabric electrode", chinese patent, 103258650.2013-08-21, 2013.

[24] E. Nemati, m. Jamal deen, and t. Mondal, "a wireless wearable ecg sensor for long-term applications", ieee communications magazine, january 2012.

[25] J. Coosemans, b. Hermans, r. Puers, "integrating wireless ecg monitoring in textiles", sensors and actuators a physical, 130-131, pp. 48–53, 2006.

[26] T. Linz, c. Kallmayer, r. Aschenbrenner, h. Reichl, "fully integrated ekg shirt based on embroidered electrical interconnections with conductive yarn and miniaturized flexible electronics", international workshop on wearable and implantable body sensor networks, ieee 0-7695-2547-4/06 , doi: 10.1109/bsn.2006.26 , 2006.

[27] M. Pacelli, g. Loriga., n. Taccini and r. Paradiso, "sensing fabrics for monitoring physiological and biomechanical variables: e-textile solutions", international summer school and symposium on medical devices and biosensors usa, ieee, pp. 1-4, sept.4-6, 2006.