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Development of Flexible Electromyography(EMG) Sensor And Instrumentation

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Abstract

There is a paucity of different detection techniques with the increasing neuromuscular and muscular disorders.SurfaceElectromyography(sEMG) is one of the most commonly used detection methods for identifying these disorders.A need for monitoring muscular activity is arising due to a shift towards sedentary lifestyle .This paper delves into a novel type of sEMG sensor and its dedicated instrumentation for monitoring muscular activity.

Methodology

1.Sensor Development: A trilayered sensor was developed for acquisition of EMG signals through the epidermal layer.Over head projector sheet(OHP) was identified to be a suitable base materialalong with silver(Ag) and AgCl which formed the other two layers of the sensor, they were coated using thermal physical vapor depositon(PVD) and spin coating techniques respectively.

2.Instrumentation Design&Development:The raw sEMG signals were processed by various stages of the instrumentation.The raw EMG signal first underwent acquisition and preamplificationstages.Filteration was carried out, with filters designed to match the desired range frequency of the sEMG signals, followed by rectification to remove the negative components.The final stage amplification strengthens the very low amplitude sEMG signals

3.Integration of Sensor and Instrumentation:The sensor and instrumentation were integrated successfully .The output sEMG was observed on the CRO.

Results and Conclusions

The output sEMG signals observed on the CRO,were found to be akin to sEMG signals found in literature. The signals showed timely variation which were in tandem with the contraction and relaxation of the muscles under consideration.These developed sensors have an added advantage over the disposable pre-gelled electrodes, they do not have a limited active lifetime,their signal to noise ratio remains high even after a significant period of time.

Keywords:

sEMG sensors;
PVD;
Spin coating;
Ag/AgCl;
Signal conditioning.

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1. Introduction

Electromyography is a diagnostic tool for evaluating electrical activity of the skeletal muscles[1] .It delves into the development, recording and analysis of myoelectric signals.Myoelectric signals are formed by physiological variations in the state of muscle fiber membranes [2]. Myoelectric signals are the electrical variations generated by the muscle cells [3].The most fundamental functional unit of a muscle is called the motor unit. It consists of an α-motorneuron and all the muscle fibers that are innervated by the motorneuron's axonal branches. The electrical signal that emanates from the activation of the muscle fibers of a motor unit that are in the detectable vicinity of an electrode is called the motor unit action potential (MUAP). This constitutes the fundamental unit of the EMG signal [4].The majority of the EMG activity is limited to the frequency range of 5 to 450 Hz[5][6] .The maximum EMG activity was observed in the range of 150Hz[5].EMG has many applications and is mainly used clinically for diagnosis of neurological and neuromuscular disorders,monitoring muscular activities and it is also used by gait laboratories and physicians who are trained in the use of biofeedback and ergonomic asessment [7] .

Measurement of EMG signal

Electrodes are needed to measure these EMG signals.These electrodes convert ionic conduction in the tissue to electrical conduction which are necessary in making measurements.The electrodes can be used singularly or in pairs,these configurations are referred to as monopolar and bipolar .The monopolar configuration has only one active electrode,which gives the changes in potential under the detection phase. The bipolar detection configuration has two active electrodes placed at a certain distance from one another, the difference in potential eliminates all the noise,thus increasing the signal to noise ratio.Usually bipolar configuration is preferred.[8]The EMG signal can be mainly be measured in two ways i.e using invasive (needle)electrodes or by using non invasive (surface) electrodes[7].Individual muscle fiber action potentials can be acquired using invasive electrodes like needle electrode,fine wire electrodes or microelectrodes[9].The peak-to-peak amplitude of a MUAP detected with indwelling electrodes (needle or wire) may range from a few microvolts to 5 mV,with a typical value of 500 µV[2] .Non invasive electrodes like surface electrodes are used to detect the signal from the localised area of the muscle under study rather than the individual direct muscle. Non invasive electrodes though give a comparatively less accurate signal,are still preferred as they are painless and hassle free to use.Most commonly used type of surface electrodes are silver /silver chloride (Ag/AgCl) electrodes.The major disadvantage of these electrodes is their short lifetime, due to the presence of conductive gel.

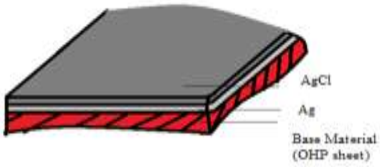

Figure 1:Schematic diagram of the Sensor

In this paper the fabricatedsensor has three distinct layers.Bottom layer being OHP sheet, silver for the central layer and the top being AgCl.Silver metal (Ag) was used because of its highly conductive and biocompatible nature.OHP sheet, made of cellulose acetate was found to be a suitable base material for the sensor,due to its flexibility and continuity.

Silver -Silver chloride electrodes were found to have acceptable standards of performance,in terms of polarization.The electrodes produce low offset voltage and were found to be non toxic with very high stability[7].

The middle Ag layer, was coated onto the OHP sheet using thermal Physical Vapor Deposition(PVD).Physical Vapor Deposition is a collective set of processes used to deposit a material(usually metal and metal oxides) in the range of a few nanometers to several micrometers[10].

In PVD technique,film quality and vacuum system pressure are inseparable,in terms of uniformity and purity.A substantially low pressure prevents oxidation and reduces the contaminants [11].Thermal Evaporation was carried out to deposit the silver under high vacuum conditions, to obtain a constant deposition rate, avoid particle collisions, and prevent heat transfer from the crucible to the wafer. [12]

Top AgCl layer was obtained using NaCl and $AgNo_3$,this was coated using spin coating equipment.

The input signal was obtained from three sensing electrodes,was given to the instrumentation.A bipolar configuration of electrodes was used, with two active electrodes along with a reference electrode. In order to observe EMG signal of the biceps contraction, the active electrodes were placed in mid and end muscle of the biceps' muscle. The reference electrode on the other hand was placed on the bony part where least muscular activity was observed.

The instrumentation was divided into three main stages,anddesigned in accordance with EMG signals' frequency and amplitude.The preamplification stage was constructed using a simple differential amplifier.

The preamplifier had a very high input impedance to match the human skin impedance.The gain of the preamplifier was low in order to reduce the effect of noise,along with high CMRR.[13]

After preamplification unit, signal was passed through conditioning unit containing various filters,rectifier and amplifiers.Low pass and high pass filter were used to remove the humps in the signal, low frequency noise and dc offset respectively.The EMG signal was rectified using a precision full wave rectifier. The precision rectifier was chosen for accurate of measurement of the small signals [14].The op-amp in precision rectifier was used in order to amplify the input voltage before it goes to the diode [15] .Rectification was followed by further amplification to obtain suitable amplitude sEMG signals.

The output of this instrumentation was given to the Cathode Ray Tube (CRO) in order to view the processed EMG signal.The surface EMG (sEMG) signal which was observed for biceps contraction was compared with the sEMG signal for biceps' contraction found in the literature.

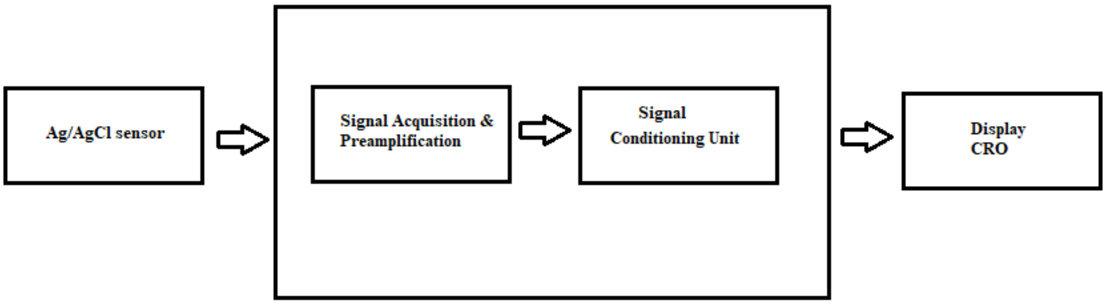

Figure 2: Basic Block diagram of the EMG system

2. Research Method

2.1Sensor Fabrication

2.1.1Preparation of Substrate:

The sensor's base material was made up of OHP sheet,which was cut into 2.5 cm x 2.5cm square pieces.The pieces were first cleaned using distilled waterand thereafter byacetone.Thesepieces were stored in an airtight ziplock pouch for further use.

2.1.2 Silver Deposition

PVD 12A4D,Hind High Vacuum Company Pvt. Equipment was used .A high vacuum of 5x10^{-5} mbar was created using roughing and backing valve,rotary and diffusion pump and ion gauge. Monitoring of pressure was done by Pirani and Penning gauges.The range ofPirrani gauge was maintained at 0.5 x10 $^{-3}$mbar .The penning gauge was fixed in the range of 10^{-2} to 10^{-6} Torr.The water supply to outlet valve was turned on to ensure the proper functioning of diffusion pump.The cleaned OHP sheet was prepared for deposition by taping it to the substrateholder.Thepiece of silver was loaded in the resistive coil .A high vacuum was reached after a period of three hours.Digital thickness meter was used to deposit 300 nm thick silver layer .The current was maintained at approximately 45 to 50 Amperes,which heated the resistive tungsten coil to incandescence to reach the melting point of silver -961^{0}C. After deposition, the current was immediately switched off.The valves,pumps and gauges were switched off, followed by mains.[16]

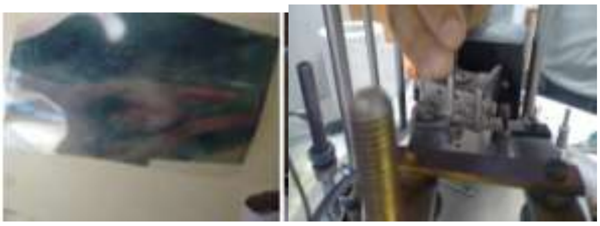

Figure3: a) b)
a)Placing silver within the resistive coil.
b)Ag coated OHP sheet.

2.1.3Silver Chloride Deposition

The top Silver chloridelayer, was prepared using sodium chloride and silver nitrate. 100ml of NaCl solution was added to10ml of $AgNO_3$solution, this process was carried out in a dark room.As a result, a white precipitate was formed indicating the presence of silver chloride.TheAgClsolution was filteredand washedthoroughly.Spin coating equipment was used to coat the AgCl layer over the Ag layer, to form the sensor. The rotation speed of the spin coating equipment was maintained at 1250 rotation per minute(rpm), for all 7 coatings.

Figure 4:a)AgCl formation Figure 4:b) Spin coating Equipment ,MCC

2.2. Instrumentation Development

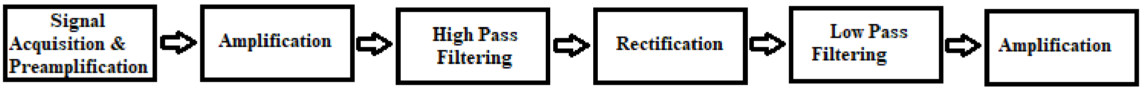

Figure 5:Block diagram of the EMG Instrumentation

2.2.1Signal Acquisition

The basic block diagram of the instrumentation is indicated in Figure 5.A precision gain differential amplifier was used for signal acquisition and preamplification.The gain of the preamplifier was set to a mid-level value along with a high input impedance.

2.2.2 Signal Conditioning

Op-amp was used as an inverting amplifier,in the signal conditioning stage.The amplifier was followed by active high pass filter to remove all the dc offset and low frequency noise[13]. The next unit of conditioning was rectification,this unit consisted of two diodes and op-amp in precision full wave rectifier mode.Thisrectified signalwas filtered, using a low pass filter. Finally, in the last unit,the signal was further amplified using an op-amp with an adjustable gain.

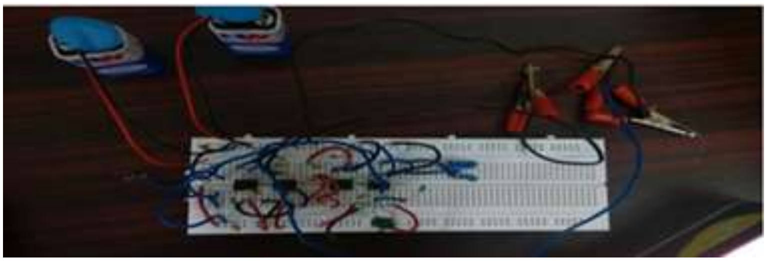

Figure 6:Image shows the complete instrumentation.

2.3 Connection and Placement of Electrodes

Placement of electrodes plays a very important role in obtaining good quality EMG signal. The electrodes were used in the bipolar configuration, for the reasons mentioned above.

The electrode wasplaced between two motor points, and along the longitudinal midline of the muscle. The longitudinal axis of the electrode (which passes through both detection surfaces) was aligned parallel to the length of the muscle fibers.Two active electrodes along the length of the muscle, with a reference electrode. The bipolar sEMG electrodes were placed around the recommended sensor location with an inter-electrode distance of 20mm,to prevent crosstalk in accordance with the SENIAM (surface EMG for a non-invasive assessment of muscles ,a European concerted action) standards.

Disposable Ag/AgCl electrodes were placed directly onto the mid and end bicep's muscles.The reference electrode was placed on the bony part,on electrically neutral tissue near the elbow.The active electrodes were attached to the instrumentation through the differential amplifier, using wire and crocodile clips.The reference electrode was given to the common ground.

Figure 7:Placement Of Electrodes

3. Results and Analysis

3.1 Sensor

A digital multimeter in resistance(Ω) mode was used to test the conductivity of the Ag coated OHP sheet, which was found to quite high.

The capacitance of the sensor was measured using a LCR meter,after establishing a silver contact over the AgCl layer.The capacitance of the sensor was found to be 1.12nF,which was found to be optimum for sensing.

3.2 Instrumentation

A signal generator and a CRO were used to test the functionality of all bocks of the instrumentation. All the individual units of the instrumentation were found to be in working order.

The output of the complete instrumentation was verified using the disposable Ag/AgCl electrodes.The sEMG signal output observed on the CRO was found to be on par with the sEMG signal for biceps' contraction found in the literature.

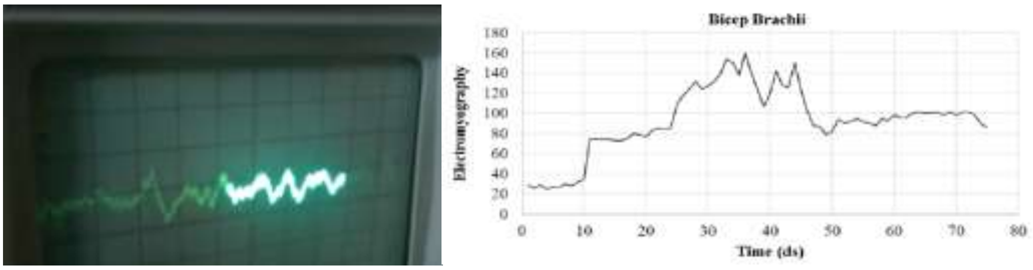

Figure 8: a b

a) sEMG signal for biceps' contraction as observed in CRO b)Theoretical sEMG for biceps'contraction

3.3 Integration of the Sensor and Instrumentation

The active disposable Ag/AgCl electrodes were replaced by the developed sensors.These sensors were taped onto the skin, crocodile clips and safety pins were used to establish the connection between the sensors and the instrumentation .The output of the system taken from the last amplification stage, was connected to the CRO.

The sEMG signal observed at the CRO was found to be on par with the sEMG signal which was found in the literature. The amplitude of the muscles undergoing contraction was observed to be higher than the amplitude of the relaxed muscles. Conclusively, sEMG signals observed on the CRO were showing a timely variation with the contraction and relaxation of the muscle under consideration.This indicated the effective functioning of the developed sensor.The sensor had an added advantage of being dry,no conductive gel was required for effective functioning of the sensor.Conductive gels are used to reduce the skin impedance.However,their usage limits the active lifetime of the sensors to 25 minutes,after which the signal to noise ratio decreases rapidly.

Figure 9:Attachment of fabricated sensors onto the skin Figure 10:Integration of sensor and instrumentation

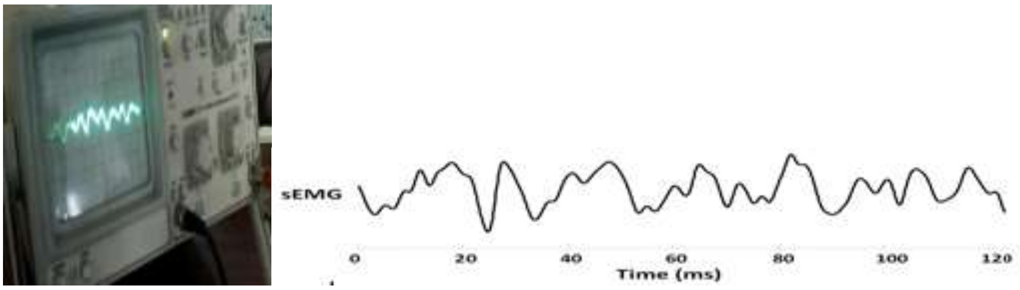

Figure 11 a b
a)sEMG for biceps' contraction signal observed in CROb)Theoretical sEMGsignal for biceps'contraction[17]

4. Conclusion

EMG plays a vital role in identifying neuromuscular disorders and disorders of motor control.Therefore, detection of EMG signals becomes cardinal.A novel type of tri-layered EMG sensor was fabricated with OHP sheet,Ag and AgCl as the three layers,where the Ag and AgCl was deposited using PVD and spin coating respectively.The raw EMG signal was processed using several amplification,filtering units within the signal conditioning block.The processed sEMG signal of the biceps' which was viewed on the CRO was found to be on par with the sEMG signal for the biceps' found in the literature.These developed sensors have an edge over the conventional ones,due to their dry nature.Due to the aforementioned reason, they can be used for various prolonged monitoring applications.Another potential application of these sensors can be recharging of pacemaker.

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References

[1]Robertson D.G.E. ,Caldwell G. ,Hamill J. et al, "Research Methods in Biomechanics*",2nd* ed. ,Champaign, IL:HumanKinestics Publ., 2004.

[2]Basmajian J.V, De Luca C.J. ,"Muscles Alive: Their Function Revealed by Electromyography",Williams&Wilkens, 5th ed.,Baltimore,1985.

[3]"Electromyography" at the US National Library of Medicine and Medical Subject Headings(MeSH).

[4] De Luca C.J.,"Electromyography :Encyclopedia of Medical Devices and Instrumentaion",Wiley,98-109, 2006

[5]De Luca C.J. ,Surface Electromyography : Detection And Recording , Delsys Incorporated,2002

[6]De Luca, Carlo J.,"The use of surface electromyography in biomechanics"*Journal of applied biomechanics* 13 (1997): 135-163.

[7]Khandpur R S, "Handbook of Biomedical Instrumentation",2nd ed.,New Delhi,India:McGraw- Hill,2003.

[8] Didier Gamette and Odette Fukapu, “Electromyography”, Laboratory of Biomechanics and Bioengineering, UMR CNMS 6600 Research Center, France

[9]Reaz, M. B. I., M. S.Hussain, and Faisal Mohd-Yasin,”Techniques of EMG signal analysis: detection, processing, classification and applications”,*Biological procedures online* 8.1 (2006): 11-35.

[10]Powell C.F ,Oxley J.H and BlocherJr J.M, “Vapor Deposition”, Wiley,New York,1967.

[11]Lofgram S.C, “ Thin Film Deposition & Vapor Technologies”,B.SThesis,PhysicsDept.,Brigham Young Univ,Id,2013.

[12]Campbell S.A ,”The Science and Engineering of Microelectronics Fabrication“,2nd ed. : Oxford University Press,2001.

[13]Wang J, Tang L, BronlundJ.E ,”*Surface EMG Signal Amplification and Filtering”,International Journal of Computer Applications* 82 (2013) :15-22.

[14]Saad I, Bais N.H, Bun S.C, Mohd. Z.H et al, “Electromyogram (EMG) Signal Processing Analysis for Clinical Rehabilitation Application*”,in 3rd International Conference on Artificial Intelligence, Modelling and Simulation 2015.*

[15]Precision Wave Rectifiers :electronics Tutorials:http://www.electronics-tutorial.net/analog-integrated-circuits/precision-rectifier/index.html

[16] Thermal Evaporationtheory,UF Chemical Engineering:http://www.che.ufl.edu/unit-ops-lab/experiments/semiconductors/evaporation/Thermal-evaporation-theory.pdf

[17]CorradoCescon, “A Portable Device To Transform Electromyographic Signals Into Music”*eContact! Online Journal for Electroacoustic Practices*,Issue 14.2