International Journal of Research (IJR) Vol-1, Issue-9, October 2014 ISSN 2348-6848

A Study on Electronic Tattoos

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Abstract –

This paper is based on a study done on 'electronic tattoos' and their applications. An electronic tattoo or an e-tattoo is a flexible, stretchable, ultrathin device consisting of a small flexible circuit that clings to the body and reads the person's heart rate, brain wave and muscular activity. This paper focuses on the construction, working and applications of an electronic tattoo.

Index terms –

Electronic tattoo, brain waves, electric signals, muscle activity, silicon chips

I INTRODUCTION

An electronic tattoo consists of basic electronic components like transistors, LEDs, transmitter – receiver pairs etc. which are manufactured with a high degree of flexibility. Hence, the electronic tattoo gets the first part of its name i.e. 'electronic'. It is called a 'tattoo' because of the way it is mounted on the skin, which mimics the fake sticker tattoos. However, it does not employ any ink or adhesive or needle unlike the original tattoos. It was patented by Mr. John A. Rogers of University of Illinois, Urbana-Champaign in the year 2011. An electronic tattoo is based on micro-electronic technology which is also known as Epidermal Electronic System or EES. EES technology was first applied in the year 1929 when this technology was not suitable for practical applications outside lab. However, the technology has been further developed and modified with time. As of now, all components are framed on ultrathin, stretchable membranes which can be easily mounted on the skin. This system was developed by a team of researchers from the United States, China and Singapore.

An electronic tattoo is very thin (lesser than 50 micrometers). In fact, it is thinner than a single strand of human hair. It measures the electric signals produced by the human beings as they perform their day-to-day activities. The user's brain waves, heart rates and muscular activities are monitored by the e-tattoo and the information is transferred to the physician. In this way, patients need not be confined to a single room to be under observation.

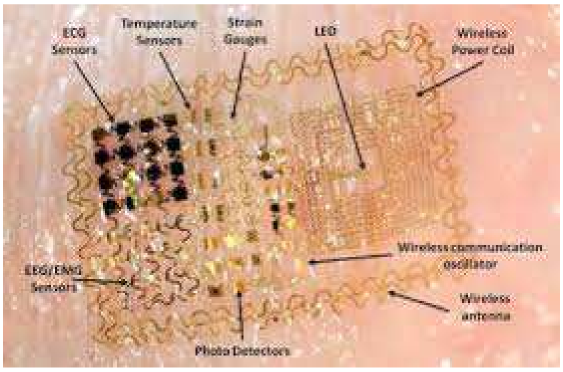

Figure 1

II CONSTRUCTION

The device includes sensors for temperature, strain and electric signals produced by the human body. It also has an LED to provide visual feedback, photo-detectors to measure light exposure and minute radio transmitters and receivers for communication. An e-tattoo requires only miniscule amounts of power. So, it can be operated using solar power or rechargeable batteries or use capacitive technology or nanotechnology or electro-mechanical technology.

The entire device is mounted on a layer of polyester above which is a water soluble sheet of plastic. The sensors are mounted on this plastic sheet in such a way that they directly face the skin. The e-tattoo is simply placed on the region where it has to be transferred. The moisture present in the human skin is sufficient to dissolve the water soluble plastic sheet. Once this plastic layer is completely dissolved, the sensors come in direct contact with the human skin. Unlike the usual sticker tattoos which get stuck because of the presence of adhesives, e-tattoos can adhere to the human skin using van der Waals force of attraction at the molecular level. Even though the magnitude of this force is considered to be very small as compared to chemical adhesives, the e-tattoo manages to stay in its position for a fortnight. In order to protect the circuit, it is sandwiched between two polarized protective layers. Some people may not be very happy with the idea of some electronic chip being stuck to their skin. Such people can wear collars or cuffs onto which the electronic tattoo would be embedded.

Generally, Silicon is available only in the form of wafers. These silicon wafers are so brittle that they would shatter like a glass utensil if dropped from a height above the ground. It is very difficult to modify the properties of a silicon wafer to make it suitable to cling onto the human skin. But, it has been observed that extracting a single layer of this wafer and modifying it to suit the characteristics of the human skin does not affect its overall performance. Any material is flexible if it is thin enough. Ideally, a silicon wafer's thickness varies from 275 micrometers to 925 micrometers. This wafer would be made up of a large number of layers, each having a thickness of 1.5 micrometers. When the thickness of the silicon wafer was reduced by a factor of 1000 then, the bending stiffness was found to have decreased by 1 billion times. So, the thickness of the entire wafer now reduces to 100 nanometers. Now, if a single layer was shaved off from this wafer, the layer would possess a high level of flexibility. But, it cannot be directly used to mount the e-tattoo onto the skin because it does not match the properties of human tissue. The human skin is capable of bending, stretching, contracting and wrapping around curved surfaces. The extracted silicon layer lacks all of these requirements. So, researchers found out a new way to compensate for this structural dissimilarity. They shifted from the layered structure to the serpentine noodle-like structure. This gets modified into wavy filaments or wires that can be elongated without affecting the silicon base. It can easily elongate or contract, depending on the need of the situation, without getting damaged. This kind of a structure can be obtained by drawing wires out of the extracted silicon layer. Even though pure silicon does not exhibit ductility, reducing the thickness to make it more flexible and then extracting a layer from the thin wafer makes it easy to draw wire-like structures from the layer. Hence, as the skin moves and deforms, the electronic tattoo moves along with it.

III WORKING

The electrical signals produced by the body are generally measured using three electrodes – the ground electrode, the recording electrode and the reference electrode. As the name suggests, the ground electrode marks the ground potential or the zero potential. This zero potential is used to define the potentials in each of the other two electrodes. The difference between these two potentials is sensed, amplified using MOSFET amplifiers and then transmitted to the display. This is how all electro-physiological measurements are done.

IV APPLICATIONS

Until the advent of electronic tattoos, monitoring a patient's brain waves, heart rate or muscular activity involved complex equipment like bulky monitors, complicated wiring, gel-coated adhesive pads etc. whose prolonged use caused skin rashes apart from a lot of inconvenience to the patients. These devices restricted the movement of patients and disturbed their sleep. Using such heavy components, along with skin-penetrating pins, to observe neonates is highly disturbing to see. Some pre-mature babies even develop infections because of being exposed to the materials used in these pieces of equipment. On the other hand, usage of electronic tattoos is less cumbersome and is preferred by most people due to the complete freedom of movement. They have innumerable biomedical applications including EEG and EMG sensors which are used to monitor nerve and muscle activity. Earlier these patches were physically connected to a computer which displayed the vitals of the patient. Now, research is being done to have a wireless transmission system to transfer the data collected by the tattoo to the computer system. In this case, not only will the data get easily transferred but, the tattoos can also be controlled externally using remote computers or smartphones.

Initially, electronic tattoos were used to monitor only the brain waves, muscle activity and heart rate. But, slowly its usage was extended to analyze pregnancies and stimulate physical movements in rats. Apart from these, e-tattoos are being used as lie detectors also. The tattoo can be mounted on the person's neck. The tattoo would consist of a skin response detector which detects the person's skin resistance. The response of a nervous and scared person can be easily differentiated from that of a confident, truth-speaking person. This tattoo was further modified into a 'throat tattoo' which was applied onto the user's neck similar to the application of the lie detector. This throat tattoo could sense the sounds produced in the throat and transfer it to a smart phone or other communication devices. In this way, the tattoo now acts as a microphone. In fact, it performs much better than a normal microphone because of its closeness to the mouth. The audio would be comparatively clearer and the background noises can be considerably reduced. In fact, if the tattoos can be synced with the mobile device wirelessly, the user would be able to receive calls with a simple voice command. The voice commands would also be capable of controlling characters in video games.

Along with the above mentioned applications, the tattoos can be designed in such a way that the sensors distinguish throat movements and hence aid speech. It has been found that when we speak to ourselves, our brain produces electrical signals which are similar to the ones produced when we actually speak aloud. The major difference between these two activities is that the neural signals do not generate complete muscle contraction and relaxation. The same thing happens when imagine performing other activities like walking, writing, dancing etc. the electronic tattoos are capable of sensing these electrical impulses and transmitting them to communication systems. So, these chips act as an aid to those who have lost their speaking ability. These people might have a damaged voice-box or larynx. Similarly, this concept can be used for communication in military operations where the sound waves produced in an oral communication can be extracted and highly confidential information can be tapped. So, using an electronic tattoo would enhance security.

In addition to the aforementioned applications, e-tattoos are being used to stimulate muscle contractions as well. Patients who have been bed-ridden for a long time and patients with new prosthetic limbs would find it difficult to move their limbs during the initial stages of their recovery. These electronic tattoos can be made to contract and relax by controlling it externally. Hence, the skin attached to the tattoos is forced to move in the desired direction. This way, e-tattoos aid in locomotion and stimulating other muscle activities.

V DISADVANTAGES

The main problem in using electronic tattoos is that they have to be regularly replaced. The human skin undergoes (amount) of wear and tear on an average. This causes the cells on the skin's surface to die. The skin constantly produces new cells to compensate for the loss. As the skin regenerates itself, the sensors mounted on the skin also get damaged and their efficiency reduces. Hence, new sensors have to be implanted on the skin at regular intervals to overcome the problems caused by sweat and degenerating skin cells.

In addition to the above mentioned issue, mounting an e-tattoo on areas like elbows and knees is very cumbersome. Also, the tattoo got dislocated well within a period of 24 hours. As of today, an e-tattoo can be applied only on the arms, legs, forehead, cheek, chin and scalp.

VI FUTURE APPLICATIONS

Researchers are carrying out experiments to make use of electronic tattoos in several other ways. The device would soon be able to heal internal wounds, cuts and burns by speeding up the healing process. The EES technology is being used by a company named MC10 in Massachusetts which will directly mount a laminated electronic tattoo in the damaged spinal cord to bridge gaps. Electrozyme is yet another company which aims to work on athletes and closely observe their performances. The tattoo would measure hydration level, fatigue level, pH values of the skin etc. and clearly display these observations to the coach so that their performance can be enhanced. Along with these devices, an electronic tattoo can be incorporated into thin thermometers which would continuously track the temperature of the user and set an alarm when the statistics are out of normal range. These tattoos can also be embedded in clothes like uniforms of workers in plants, players, mining areas etc. where in there would be a vast transition in the temperature of their surroundings. So, if the tattoos can monitor the temperature of the user's surrounding, they can modify the temperature of the clothes worn by the users in such a way that the users feel comfortable. Researchers are also working on diagnosing and preventing seizures by measuring the heart rates and other electrical signals produced by the brain. In the near future, it would also be possible to predict an impending heart attack using these electronic tattoos.

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