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WEARABLE SENSOR SYSTEMS INSPIRED BY NANOMATERIALS

Ashima Yusuff

Student

School of Electronics and Communication Engineering

B.S. Abdur Rahman Crescent Institute of Science and Technology, Chennai, India

Abstract: *Wearable sensors systems have been substantially incorporated in every aspect of our daily lives in the recent years. With the growing demand to find alternative methods for flexible, convenient, user-friendly, and wearable power sources that can be attached with the human skin, wearable sensors have now been incorporated with Nanomaterials. With their appreciably expanded surface area and promising material properties, these materials have paved the way for enhancing the future of wearable electronics. Wearable sensing systems can only be comprehended when they are integrated with high performance sensors that have significant multi-functional properties. Nanomaterials lay a platform for such wearable sensors that are distinctly used to closely monitor the body signals as well as human activity incessantly in real time. Representative applications for wearable systems incorporated with Nanomaterials including remote health monitoring, drug delivery applications, tracking sports and daily activity are highlighted. Followed by other applications like contact lenses, dermal implanted sensors and smart tattoos are conferred. The key aspects that ought to be noted while choosing the types of Nanomaterials have also been discussed.*

***Index Terms* - Wearables, sensors, nanomaterials, monitoring.**

I. INTRODUCTION

Wearable sensors that can be laminated on the skin have served to be useful not only in academia but also in the industry, as well. Wearable sensors that can be laminated on the skin have served to be useful not only in academia but also in the industry, as well. Wearable biomedical electronic devices especially prove to be highly effective in monitoring chronic diseases such as hypertension, asthma, diabetes or life-threatening experiences like seizure and cardiac arrest. For the treatment of chronic diseases environmental conditions like ambient temperature, harmful radiations, humidity levels and presence of harmful gases or air-borne particles in the surroundings need to be tracked which is carried out by high performance wearable sensors. In addition to clinical, applications of wearable sensors, we can also track daily sports activities to examine the performance and well-being of athletes. For the past one decade, most research in this field has relied upon rigid devices made from silicon and compound semiconductors. This brought about a mechanical mismatch between the rigid electronic counterparts, and the soft human skin leading to a root cause of several problems. These problems, thus, shed light on forthcoming Nanomaterials that possess unusual physical properties that drastically improve the performance of sensors and are highly elastic, flexible and comprise high surface area. They also contain good mechanical and electrical properties, excellent Electrochemical stability and have low-cost of fabrication, thus they are employed as the building blocks in the development of wearable sensors.

In this paper, we commence with a brief overview of the Nanomaterial properties that are integrated in wearable sensors. Followed by the discussion of an assortment of wearable sensors in terms of the medical applications in Section 2 , the miscellaneous applications of wearable sensors in Section 3, the key aspects to keep in mind while incorporating Nanomaterials used to make wearable technology will be arguemented in Section 4 and the conclusion of the paper will be discussed at the end.

1. Properties of Nanomaterials- What Makes Nanomaterials Our Primary Choice?

Nanomaterials are full of unique properties that make them suitable to be used in wearable sensors. Their unique properties include large surface area, optically active, they are mechanically strong and chemically reactive. They possess other functionalities such as water and dirt repellent, ultraviolet radiation protection antibacterial and flame resistance that makes them known in the textile industry as well. They also possess certain magnetic and thermal properties which exhibit electrical conductivity between semiconductors and metals that enable researchers to use them in wearable biomedical electronic devices.

2. Diverse Wearable Sensor Systems in The Medical Field

Nanomaterials enabled wearable sensor systems show immense potential in a wide variety of applications in healthcare. In this section, we will focus on the applications of continuous health monitoring, tracking sports activity and drug delivery.

2.1. Health Monitoring

Wearable sensors that are laminated on the skin or integrated via textiles enable the real time monitoring of various physiological parameters and environmental conditions. These help to switch from the high cost hospital-centred healthcare to a considerably low-cost customized home care. This shift also helps the ageing population and older citizens who cannot afford to be under supervision at all times. Wearable sensors can therefore sense parameters of diverse diseases and can either transfer their current data to a remote centre, direct the patient to carry out a specific action, or it may automatically perform a function based on the reading of the sensors. Apart from physiological variations like blood pressure, respiration, body temperature the implanted technologies can also be used to detect subtle deformations that are induced by body activity such as blood pulse flow or even movements of fingers and knees can be detected by Nanomaterial based mechanical sensors. The treatment of cardio-vascular diseases requires continuous monitoring of electrocardiogram (ECG). Nanomaterial enabled electrode have been imposed for long-term ECG sensing that does not cause any irritation to the skin. Heart rate monitoring keeps a close check on the mental, and physical state of an individual. This can be calculated by closely accessing the R-R peak in the ECG signal. Graphene-based strain sensors represent a complimentary tool for ECG analysis.

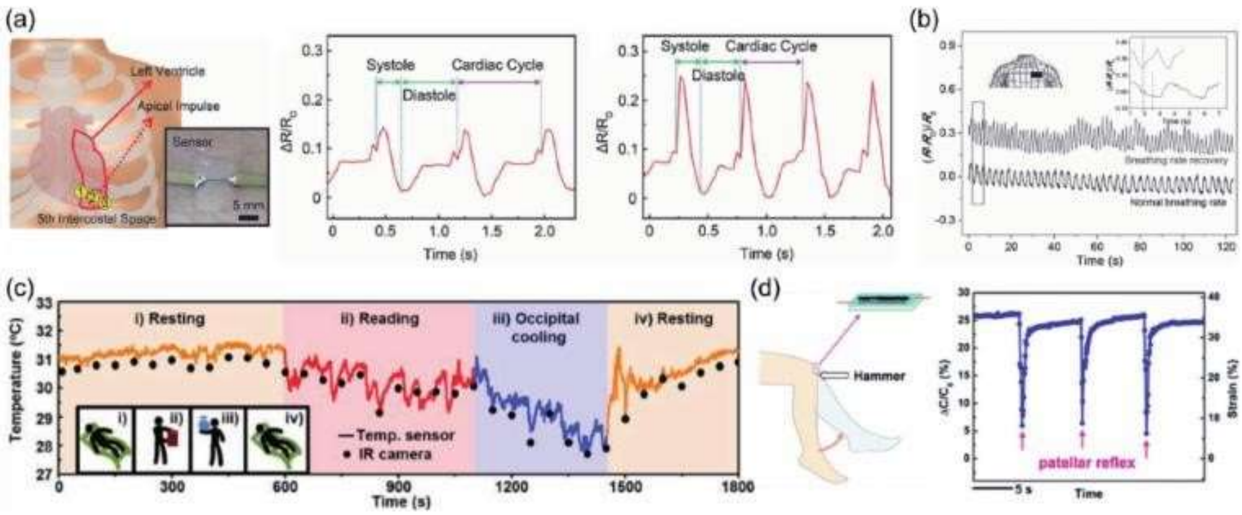


Figure 1. Applications of nanomaterial-enables wearable sensors in health monitoring a) An AuNP based resistive strain sensor attached to the chest at site 2(left) and the corresponding ACG contour detected before(middle) and after(right) exercise. Reproduces with permission. b) Relative resistance changes of a graphene-based strain sensor corresponding to the respiration under normal and exercise state. The inset shows the sensor attached on the chest. Reproduced with permission. c)Body temperature changes during various activities detected using a resistive temperature sensor (as shown in Figure d) The schematic illusion of the setup of the patella reflex experiment(left), and the relative capacitance change associated with lower leg motion during patella reflex experiment measured by the strain sensor(right). Reproduced with permission. Copyright 2013, Royal Society of Chemistry.

The diagnosis of diseases like sleep disorder, asthma and anaemia is done by monitoring the respiration rate of an individual which is assessed by measuring the respiration rate using wearable strain or placing pressure sensors on the chest which can be viewed in the above figure. For patients suffering from frequent and unexplainable fainting episodes, long-term monitoring is required to provide the right diagnosis. Monitoring motion patterns of Parkinson's patients can be done at home, and the severity of Parkinsonian symptoms can be inferred.

2.2.Drug Delivery

A graphene-based nanomaterial wearable system can be used in drug delivery. It comprises normally of a strain sensor, a wearable Light Emitting Diode, a heat generating device and iontophoresis electrodes. The heater can thus provide the temperature for any kind of thermal therapy and the iontophoresis electrodes can trigger the drug delivery across the skin.

For diabetic patients a wearable diabetes patch is designed, that consists of multiple wearable sensors, a sweat collection system and a micro-needle array, when the blood glucose levels increase at a high rate, they can be measured by a strain sensor and the patient's sweat can be collected for glucose sensing. As a response to the glucose level, temperature-controlled drug release can be done by heating the micro needle array enabling the trigger of the drug release through the micro-needle.

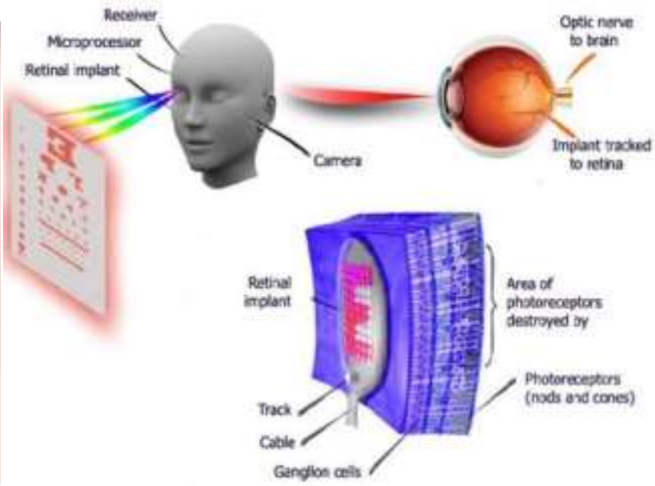
2.3.Sports Tracking

Analysis of the daily sports activities help to provide valuable information on well-being and fitness of the human body which is important to provide feedback during rehabilitation. Such information like finger and knee bending and forearming movements can also be developed from wearable strain sensors that have a large strain detection range. A carbon nanotube-based strain sensor is used for the detection of knee motions during flexing, marching, squatting, and jumping for which both intensity and frequency of the motions can be identified. Heart rate, respiration rate, body motions, and other parameters collected from wearable sensors systems help to provide fundamental information to improve the performances during rehabilitation, or sports. Continuous monitoring of sweat during exercise can be performed using wearable Electrochemical sensors. These types of analysis allow the real-time estimation of the physiological and metabolic state and gives important information for disease diagnosis and athletic performance evaluation.

3. OTHER WEARABLE SENSORS

The health monitoring benefits of incorporating Nanomaterials in wearable sensor systems has invoked a wide scope of development in fields other than health monitoring. Researchers are coming up daily with distinctive ideas for the incorporation of Nanomaterials assisted devices. Some advancements under research in this field are as follows.

3.1.Contact lenses

Contact lenses coated with Nanomaterials like graphene are widely used across the world which makes physical contact with the surface of the human eye and tears. Graphene being a superb conductor is used inside contact lenses as a wearable system for medical sensing, researches for the development of smart contact lenses is still being carried out. These lenses perform functions such as diagnosing retinal disorders, diabetic eye problems and problems like conjunctivitis detecting. Continuously monitor the health of the patient through continuous contact with the eyes, and tears is the ultimate goal of smart contact lenses.

3.2.Dermally-Implanted Sensors

Blood chemistry researchers are working on nanoparticles that can be injected into the highly vascular dermis layer of the skin and change colour to reflect changes in blood chemistry. These

"active" inks are luminescent; hardly noticeable to the naked eye and visible only by using a special light mechanism. This benefited in tracking and locating applications.

3.3.Smart Tattoos


Smart tattoos can be used to monitor heart arrhythmia, sleeping disorders and the heart activity of premature babies and also serve as a human-computer interface when applied to the throat by using vibrations from the larynx to control a computer. Additional detectors, transmitters and receivers can also be included on the tattoo which enables transfer of information to hospital centres or to other integrated devices attached on the body.

4. Being Precautious with Nanomaterials

Nanoparticles with their extraordinary properties like antibacterial, ultra violet radiation protection, water and dirt repellent properties establish a major contribution to wearable sensors. But they also have a downside that is the growing concern regarding consumer exposure. The most important route of exposure being the case of dermal contact. Nanoparticles maybe released on the human skin due to abrasion, change in temperature, washing or other effects in the case of wearable technology which leads to growing need of finding out methods to incorporate them wisely. Nanoparticles are generally produced in the form of nanofibers in the case of textiles where they are commonly mixed with organic polymers which are previously dissolved by solvents, this poses a lower risk in terms of the harmful effects caused by the dermal exposure of nanomaterials in the case of wearable nanomaterial fabricated devices. This process incorporates the nanoparticles firmly in the textile fibre and assures a good adhesion on the surface of the textile. To create effective nanotextiles, nano-silver containing materials are used, which ensures the colloidal silver properties of silver and large surface of nanoparticles to be infused together. Silver being a natural antibiotic since ancient times can prove to be effective against bacteria, fungus and some viruses in people, says recent studies. But the harmful effects caused by the ingestion of these nano-silver materials is still debatable.

II. CONCLUSION

In this paper, we have discussed that wearable sensor systems are the future of tomorrow as far as biomedical devices are concerned, and we have highlighted that these wearable sensors are high stretchable and sensitive that they are used significantly in health monitoring, sports tracking, and even drug delivery across the skin. Concerning materials, we need to improve the understanding of Nanomaterial properties and take measures to reduce the harmful effect that can be caused by the impact of Nanomaterials on the skin. The fabrication and processing methods development are in demand to achieve low-cost, high performance, and reliable and user-friendly sensors. The miscellaneous applications of wearable sensor systems discussed include contact lenses, dermally implanted sensors and smart tattoos. Thus, Nanomaterials enabled wearable sensor systems have an ocean of scope in the field of healthcare that are being developed ubiquitously in the global market.

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