IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Impact Factor 8.102 ⋇ Peer-reviewed journal & Refereed journal ⋇ Vol. 12, Issue 11, November 2023

DOI: 10.17148/IJARCCE.2023.121126

IoT Enabled Respiratory Sensing Device for Pressure Sensor

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Abstract: The market for Internet of Things (IoT), wearable and flexible electronics, and sustainable development is projected to exceed $500 billion during the next five years. This encompasses a range of technologies such as sensors, micro electro mechanical systems (MEMS), medical instruments, energy harvesting and scavenging devices that enable the IoT, as well as energy-efficient systems. This is owing to our capacity to create materials differing from metals, insulators, metal-oxide, semiconductors and organic polymer materials or hybrid mixed phase materials in diverse stages including amorphous, nanoclusters or various phases of crystallization. Therefore, this allows for the creation and manipulation of materials with diverse characteristics and capabilities on various surfaces, such as flat, flexible, and conformal ones. The primary aim of this research was determined based on a comprehensive examination of existing knowledge, the increasing difficulties, and the practical constraints within the academic setting.

Keywords: IoT, Pressure Sensor, Wearable Electronics, Smart garments.

I. INTRODUCTION

The development of small-scale gadgets used in medical applications has led to a significant increase in the popularity of wearable technology. Wearable electronics, such as hearing aids, pacemakers, and other medical equipment, have been used for many decades. The rise in consumer demand and the increasing number of elderly individuals have led to the development of wearable electronics for various purposes, such as entertainment, activity tracking, and health monitoring. Wearable technology also enables the monitoring, recording, and transmission of physiological signs, so allowing hospitals to allocate their space for more urgent and prompt treatment. The physiological bioelectric signals include Electrocardiograms (ECGs), Electroencephalograms (EEGs), Electrooculography (EoG), Electromyogram (EMG), body temperature, blood pressure, and everyday activities.

II. METHODOLOGY

The wearable solutions include fitness bands, smart eyewear, smart clothes, and other medical gadgets. Figure 1 depicts wearable clothing equipped with embedded sensors designed to detect the location and movement of the arm in the context of neurorehabilitation. There are several obstacles with these designs. Electronics integrated into fabrics must possess qualities such as flexibility, washability, comfort, and unobtrusiveness to the wearer.

Fig 1. Smart garments embedded with sensors used in neurorehabilitation

Wearable electronics are often used to locate survivors of battlefield casualties, enabling timely medical assistance during the critical "golden hour". Flexible sensors integrated with wearable electronics are used for the purpose of monitoring the ingestion of nutrients and minerals via the mouth. Figure 2 displays an oral sodium sensor equipped with integrated electronics, which is used for the estimate of salt consumption
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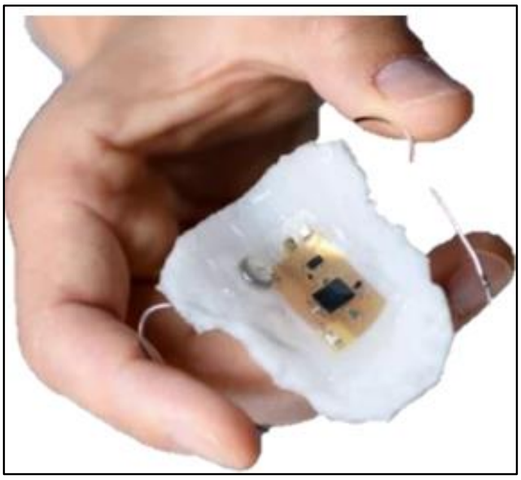

Fig 2. Oral sodium sensor with integrated electronics to monitor salt intake.

Figure 3 depicts the use of flexible capacitive electrodes that are affixed to a belt designed to be worn on garments. This setup serves the purpose of minimizing skin irritation and capturing ECG readings. These designs are extensively tuned to minimize motion artifacts in order to get accurate measurements.

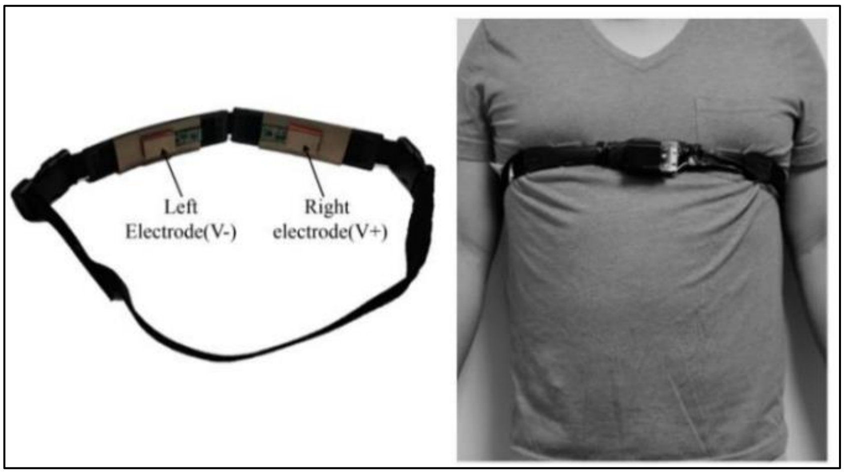

Fig 3 Flexible capacitive sensors mounted on a belt to be weared on chest to monitor ECG signals

Multiple sensors, often known as electrodes, are used to detect and quantify bioelectric signals that are created as a result of induced pressure caused by muscle action and increased blood flow in blood vessels. Conventionally, moist electrodes are positioned on the skin with an intermediate layer of conductive gel. Nevertheless, electronics using wet electrodes naturally provide several disadvantages, such as pain, lengthy setup time, skin irritation, and an inability to guarantee long-term stability.

Occasionally, the use of wet electrodes may need skin preparation, which might lead to complications, particularly in newborns. Several researchers have suggested techniques for creating flexible dry electrodes that can adhere to the skin without the need for conducting gel. The rigid dry electrodes shown in figure 4 operate based on the idea of capacitive coupling between the electrode and the skin. This is unsuitable for sustained, extended measurement over a prolonged period. Piezoresistive and capacitive pressure sensors are often manufactured as MEMS devices, which include conditioning circuits and a digital interface to facilitate seamless integration.

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2.1 Pressure Sensor

A pressure sensor is a device that detects pressure and turns it into an electrical signal. These sensors have been extensively used in several fields including as manufacturing, automotive, aerospace, and biomedical applications. Sensors based on MEMS technology demonstrate compact dimensions, affordable pricing, and exceptional efficiency. The sensors are coated with durable materials to shield them from external factors. Pressure sensors have a wide range of uses in a person's everyday life, such as measuring displacement, detecting sound waves, harvesting energy, and monitoring health in the field of biomedicine. Pressure sensors are often categorized according to their sensing platforms and the specific physical characteristic they measure, such as piezoelectricity (force or potential), capacitance, and resistance.

2.1.1 Piezoelectric Pressure Sensors

These pressure sensors detect changes in external pressure by measuring the corresponding variations in electric potential. The piezoelectric material produces an electric signal when it is subjected to mechanical deformation or strain. Piezoelectricity relies on the principle of electrical dipoles and the ionic bonding in the crystal structure of piezoelectric materials. When the dipole is in a state of rest, the positive and negative ions inside it nullify each other's effects because of the symmetry of the crystal structure. Consequently, no electric field is produced. When a piezoelectric material is exposed to stress, it deforms and loses its symmetry, leading to the creation of a net dipole moment. This results in the generation of an electric field across the crystal, and vice versa. These sensors are often equipped with a diaphragm that deflects when force is applied.

The piezoelectric sensors made from semi-crystalline polymer films provide excellent elastic compliance and a wide dynamic range ranging from 10−8 to 106 psi or µtorr to Mbar. Moreover, the polymer films provide exceptional dynamic range and stability in the surrounding environment, as well as robust mechanical strength combined with impact resistance. Figure 4 illustrates a piezoelectric sensor constructed using synthetic Lead Zirconate Titanate (PZT) ceramic material. The PZT has the most elevated piezoelectric and electrical-mechanical coupling coefficients, making it very desired for sensing applications. Additionally, the production procedure for PZT is straightforward and cost-effective when compared to other piezoelectric materials. These sensors are used in the aerospace, medical, mobile phone touch pad, and automobile industries. Piezoelectric sensors have many limitations: they are unsuitable for static measurement, prone to brittleness, exhibit high impedance, and experience decreased accuracy at high temperatures. Currently, there is a growing endeavor to reduce or abstain from the utilization of lead in these piezo sensors.

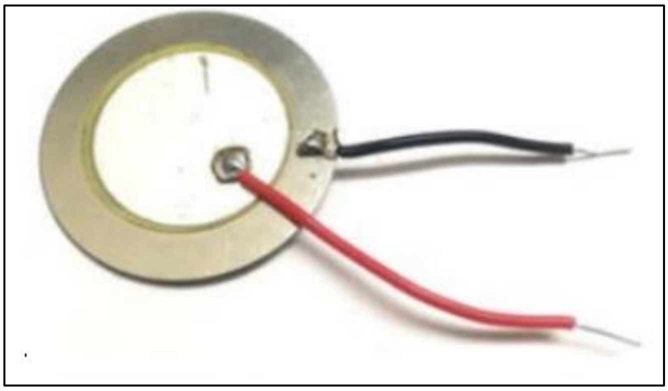

Fig. 4. Synthetic ceramic based piezoelectric sensor

2.1.2 Piezoresistive Pressure Sensor

These pressure sensors measure changes in the electrical resistance of a substance when force or pressure causes deformation. Only materials with high sensitivity among the many piezoresistive materials may be used as sensors. Semiconductors such as silicon have piezoresistive properties. Conductive dopants may be added to elastomers to make them piezoresistive.

The piezoresistive sensors offer high mechanical and electrical stability that may be produced in a very tiny size. Figure 5 depicts the MPM150 piezoresistive pressure sensor, which utilizes MEMS technology and is designed for measuring the pressure of non-corrosive gases or liquids. The sensing element comprises a silicon chip with a flexible diaphragm and four integrated resistors that create a Wheatstone bridge. When the diaphragm is subjected to pressure, the piezo resistors in the bridge circuit generate a voltage that is directly proportional to the applied pressure.

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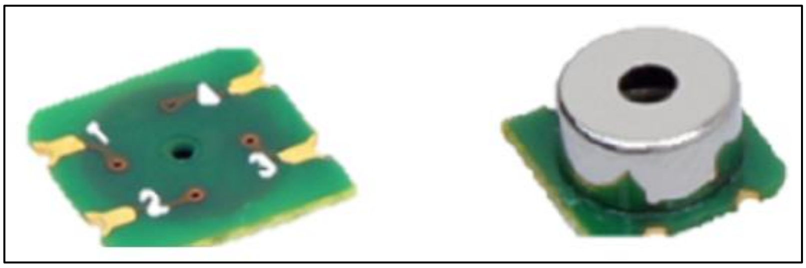

Fig. 5. MPM150 MEMS-based piezoresistive pressure sensor

2.1.3 Piezocapacitive Pressure Sensor

In these particular sorts of sensors, the alteration in capacitance is acquired when the applied pressure causes the diaphragm to bend, thereby modifying the distance between the parallel plates of a capacitor. The change in capacitance is often seen by tracking the frequency fluctuation of the oscillator's output or by adjusting the intensity of an alternating current pulse.

Typically, MEMS-based capacitive sensors are equipped with highly accurate sigma-delta analog-to-digital converters (ADCs) that are compatible with either the Serial Peripheral Interface (SPI) or Inter IC Communication (I2C) interface. These sensors are used for measuring low pressure inside the mbar range. Figure 6 displays the PPCP3-M1 MEMS silicon capacitive pressure sensor. The device may be programmed to function in either differential mode or gauge mode.

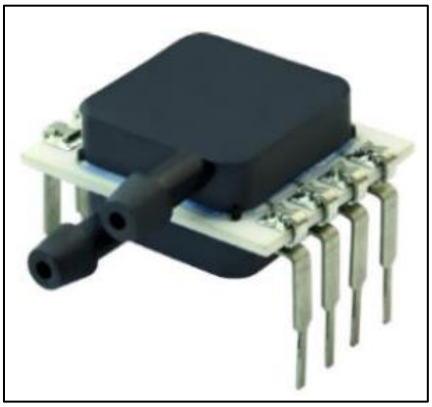

Fig 6. PPCP3-M1 MEMS silicon capacitive pressure sensor

2.2 Pressure Sensors in Wearable Electronics

Wearable electronics are used to monitor the signals produced by the physiological systems of the human body. The data obtained from these involuntary physiological signals may be collected to analyse the condition of physiological systems. Diagram 6 illustrates many physiological indications that are obtained via the use of pressure sensors. The amplitude of these signals ranges from 1 µV to 100 µV, and they have a low frequency. The occurrence of potential deterioration in the patient's condition is identified and examined using collected data. Instances of abrupt alterations in respiration and pulse rate often serve as signs of critical medical emergencies, including cardiac arrest, suffocation, sudden newborn death syndrome, obstructive sleep apnea, and others.

The EoG method is used to quantify the movement of the eye pupil, as seen in Figure 7(a). Figure 7(b) displays the measurement of blood pressure volume, whereas Figure 7(c) shows the measurement of head volume. The pressure resulting from the functioning of the heart and muscles is measured using ECG and EMG techniques, respectively (as shown in Figure 7(d) and (e)). The monitoring of lung activity, namely the rate and depth of breathing, inside the thoracic cavity is achieved by using pressure sensors, as seen in Figure 7(f). Traditionally, Ag/AgCl electrodes are used to record the biopotentials. Before applying these electrodes, it is essential to prepare the skin by shaving and washing it with alcohol. Prolonged use of gel may lead to allergic contact dermatitis, and frequent application of the gel might cause noise owing to an unstable interface between the skin and the gel. The use of dry electrodes requires a complex analog front end to serve as the interface between the skin and the electrode. This introduces an extra phase shift into the recorded signal, particularly in ECG measurements.

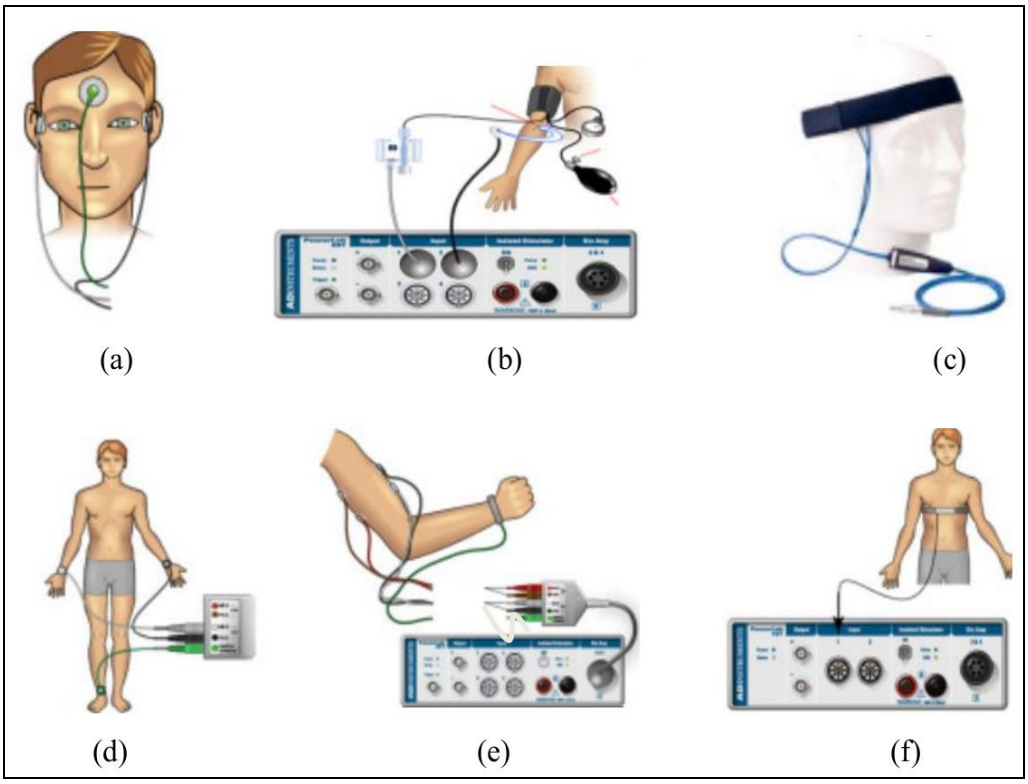
(a) (b) (c)
(d) (e) (f)

Fig 7. Physiological biosignals (a) EoG (b) Blood pressure-volume (c) Head blood volume pulse (d) ECG (e) EMG (f) Respiration

2.3 Flexible Sensors for Wearable Electronics

Precise and accurate sensing is required from flexible and wearable sensors while ensuring user comfort and natural motions are not compromised. For long-term monitoring, wearable sensors must adhere to certain standards for medical and ergonomic needs. The system should possess compact dimensions and its components should exhibit flexibility, comfort, chemical inertness, hypoallergenic properties, and non-toxicity to the human body. Therefore, the crucial attributes that constitute flexible sensors are skin conformability and stretchability. These capabilities may be attained using flexible thermoplastic polymers like poly urethane (PU), PolyEthylene Terephthalate (PET), and a category of soft silicone elastomers. PDMS is chosen specifically for its exceptional optical clarity, outstanding ability to deform, and simplicity of production. Essentially, this collection of pliable elastomers provides a significant level of flexibility when applied to surfaces of varying shapes and textures. Organic polymers may be engineered to demonstrate piezoelectric characteristics, enabling their use as pressure sensors in a wide range of flexible electronic applications.

The surface qualities of biomaterials that directly interact with the human body are crucial for their integration into human tissue, necessitating precise management. Organic thin films and coatings, particularly those composed of polymers like PDMS and PVDF, are used for biomaterial coatings because of their exceptional versatility. The mechanical characteristics of these materials are compatible with those of pliable biological tissues. The considerable interest in organic thin films is also driven by the advantage of simplified processing. PDMS and PVDF provide the necessary characteristics of flexibility, biocompatibility, chemical inertness, comfort, and ease of synthesis, making them highly suitable for usage in wearable electronics applications compared to other polymers.

III. CONCLUSION

The purpose of this paper is to give a comprehensive examination of the wide variety of emerging materials that are being considered for sensor applications in the International Roadmap for Devices and Systems (IRDS). An investigation is conducted into the importance of using organic polymer materials and the relevance of these materials in wearable electronics. Polymers and carbon-based nanomaterial’s, which display traits such as flexibility, biocompatibility, and varied properties suited for a variety of applications, are the subject of a survey that is being conducted into the possible applications of these materials.

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