REVIEW-3

TOPIC: PROGRESS OF FLEXIBLE ELECTRONIC DEVICES IN E-TEXTILES FOR MEDICAL APPLICATIONS

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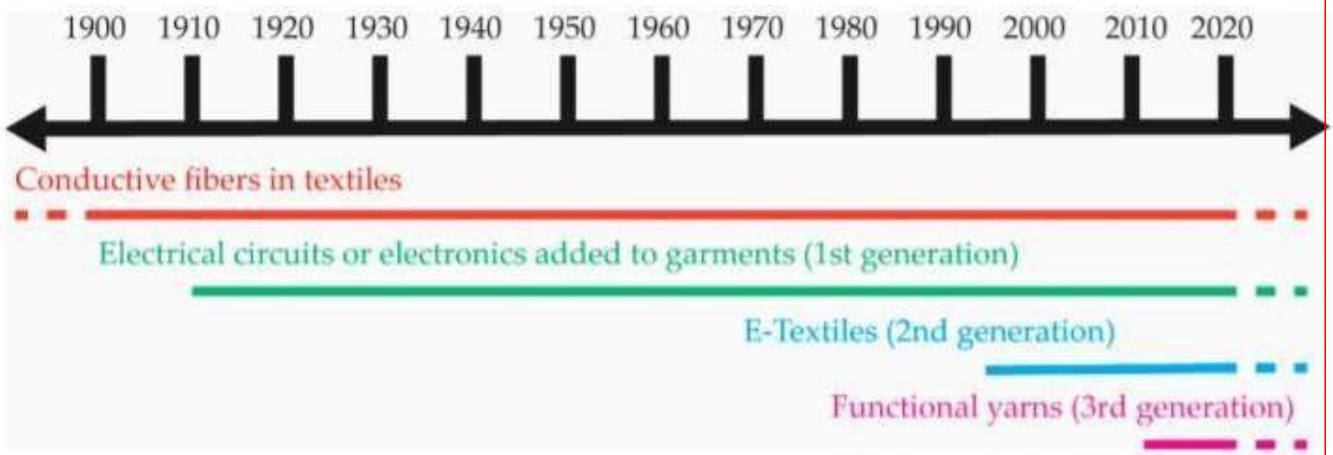
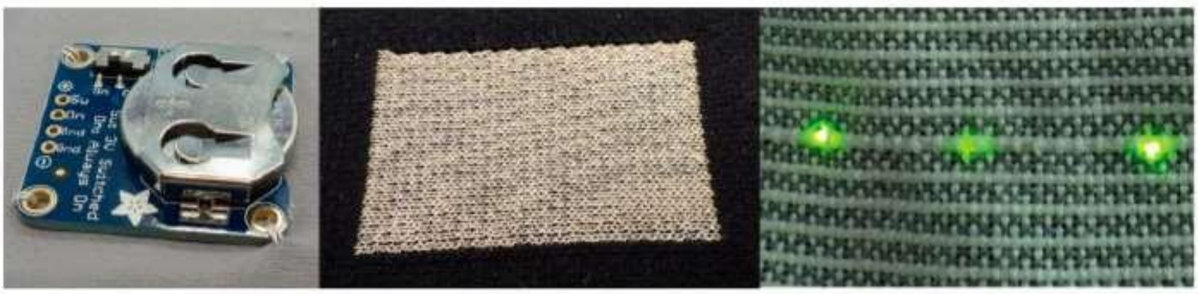
A HISTORICAL REVIEW OF ELECTRONIC DEVICES IN e-TEXTILES

Textiles have been at the heart of human technological progress for thousands of years, with textile developments closely tied to key inventions that have shaped societies. The relatively recent invention of electronic textiles is set to push boundaries again and has already opened up the potential for garments relevant to defence, sports, medicine, and health monitoring.

Timeline





(b) (c)

Fig(a):adafruit coin cell battery holder

Fig(b): knitted electrode
Fig(c):functional yarns

Applications of Flexible electronic devices in medicine

- *CONTINUOUS HEALTH MONITORING*
- *IMPROVING SURGICAL PROCEDURES*
- *CONTROLLING DISEASE CONDITIONS*

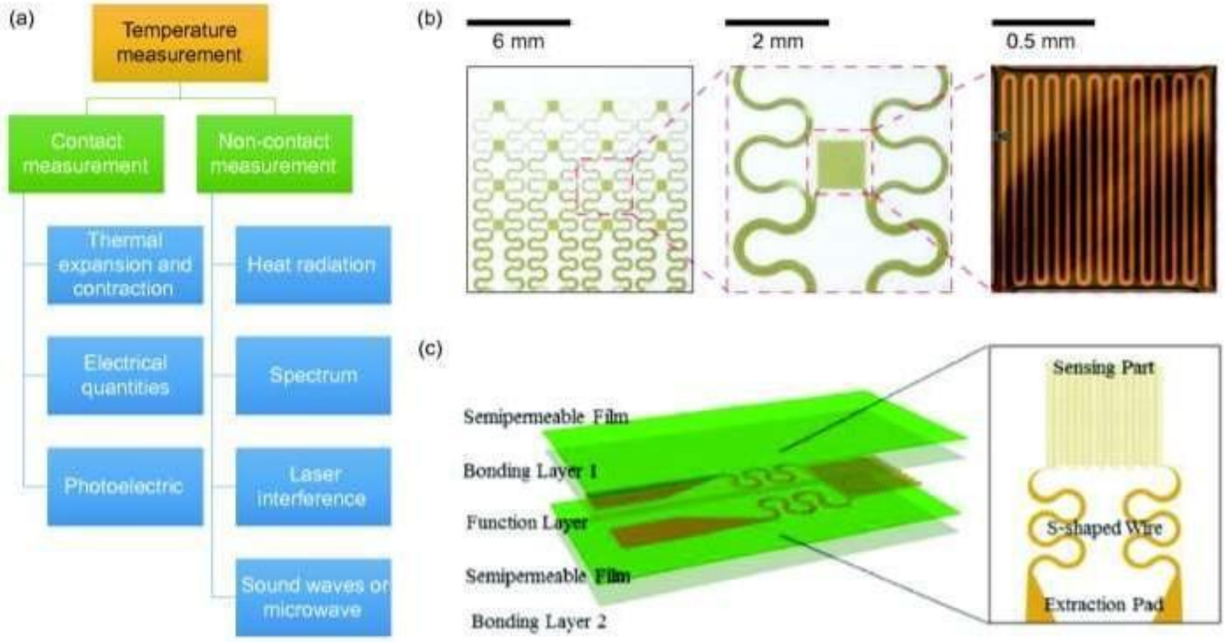
1)SIGNAL MONITORING BY FLEXIBLE ELECTRONICS

Flexible electronics provides circuits with the capacity to withstand the strain of high level deformations without fracture or significant degradation of their electronic properties. Over the past several years, many impressive potential applications of these electronic devices have emerged, particularly in the area of biomedical and wearable devices . Furthermore, a large number of related patents have been authorized. Signal monitoring is crucial for different application scenarios of flexible electronic devices.

1.1)TEMPERATURE MONITORING

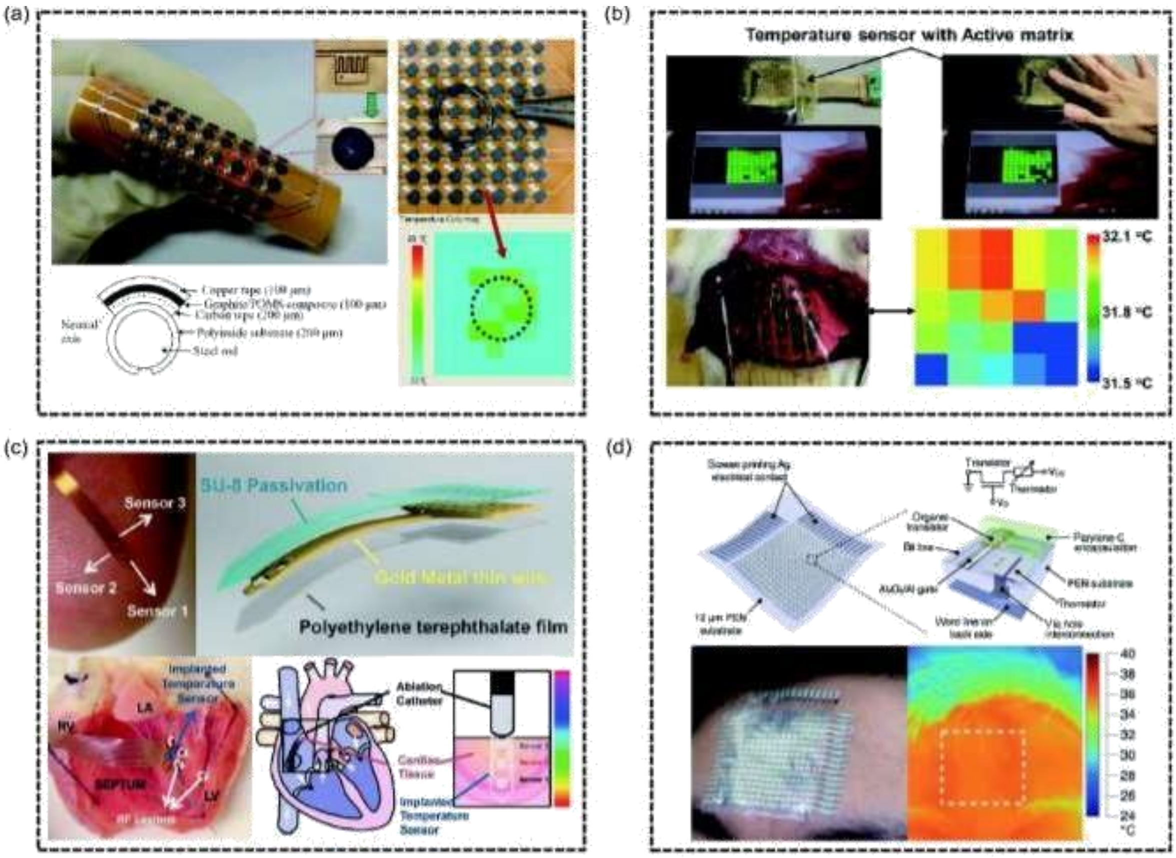
Human body temperature is a basal index in physiology because of its importance and close relationship with various human body parts. Long-term real-time monitoring of temperature is of great significance in clinical medicine, especially for tracking the healthcare quality of new-born babies or patients under anesthesia.

Traditionally, body temperature was taken to be the axillary temperature measured by a mercury thermometer. However, this method is not suitable or convenient for the babies or patients who are not able to keep still.



A feasible and practical solution is flexible and wearable temperature equipment. The epidermal temperature sensors can be adhered to the skin and can accurately measure the body temperature by minimizing the environmental influences.

Fundamental investigations on the sensitivity, response time, and accuracy were also conducted via the analytical, numerical, and experimental approaches. More recently, a highly accurate temperature sensor based on polysilicon thermistors has been developed for monitoring brain temperature with high spatial resolution , and this temperature sensor has a response time of 1.5 s and sensitivity of −0.0031°C-



a) temperature sensor array and temperature distribution subjected to a heat source.

b) temperature mapping of a finger tip and a rat lung

c) ultra thin injectable thermal sensors and a device injected to a myocardial tissue

d) schematic diagram of a flexible temperature sensor and a measured temperature distribution of forehead.

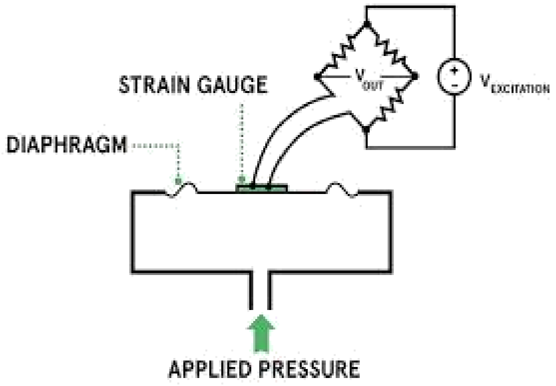
Efforts are still being made to develop various flexible temperature sensors and devices because these devices have a wide range of applications in sectors, such as human health management, food processing, and pharmaceutical industry.

Pressure monitoring

Flexible pressure sensors are becoming increasingly popular because of their wide potential applications in areas such as electronic skin systems and diagnostics . In general, the pressure-sensing technology can be categorized into three types: **capacitive , piezoresistive and piezoelectric** A disadvantage of these sensors is that they generally suffer from high deformation when used for monitoring human health, especially when these are directly laminated onto the skin surface. To mimic the tactile sensing properties of natural skin, large arrays of pixel pressure sensors on a flexible and stretchable substrate are required .

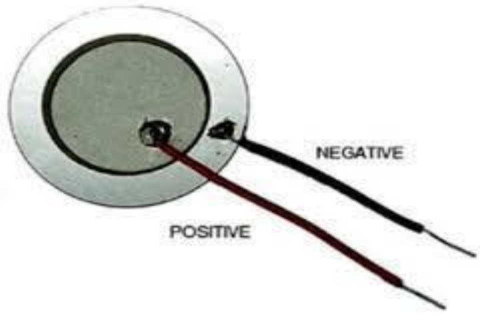
PIEZORESISTIVE SENSOR:

A **piezoresistive sensor** is a flexible strain gauge that becomes resistive when mechanical deformation is applied.



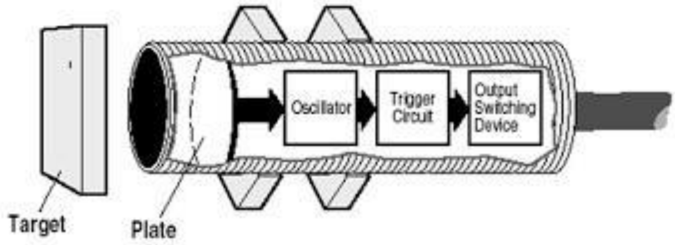
PIEZOELECTRIC SENSOR:

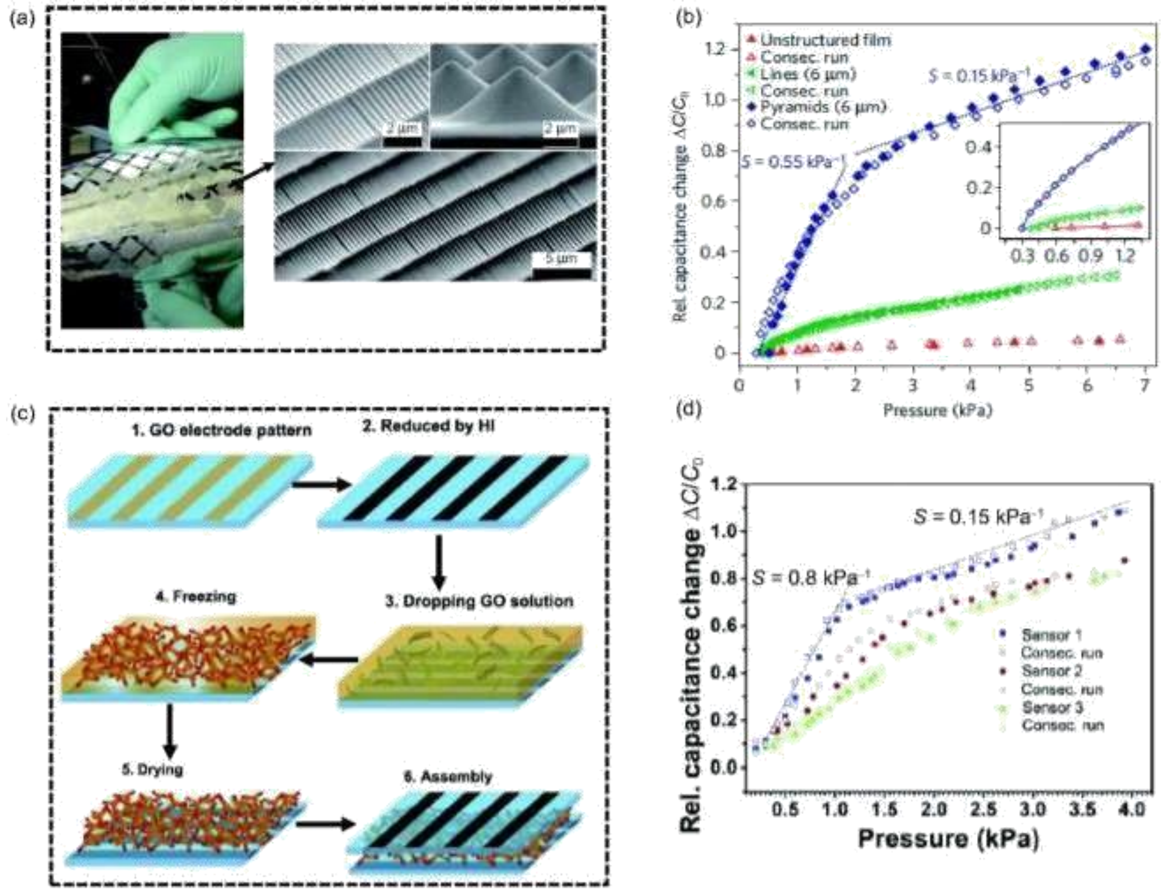
A **piezoelectric sensor** is a device that uses the **piezoelectric** effect, to measure changes in pressure, acceleration, temperature, strain, or force by converting them to an electrical charge. The prefix **piezo**- is Greek for 'press' or 'squeeze'.



CAPACITIVE SENSOR:

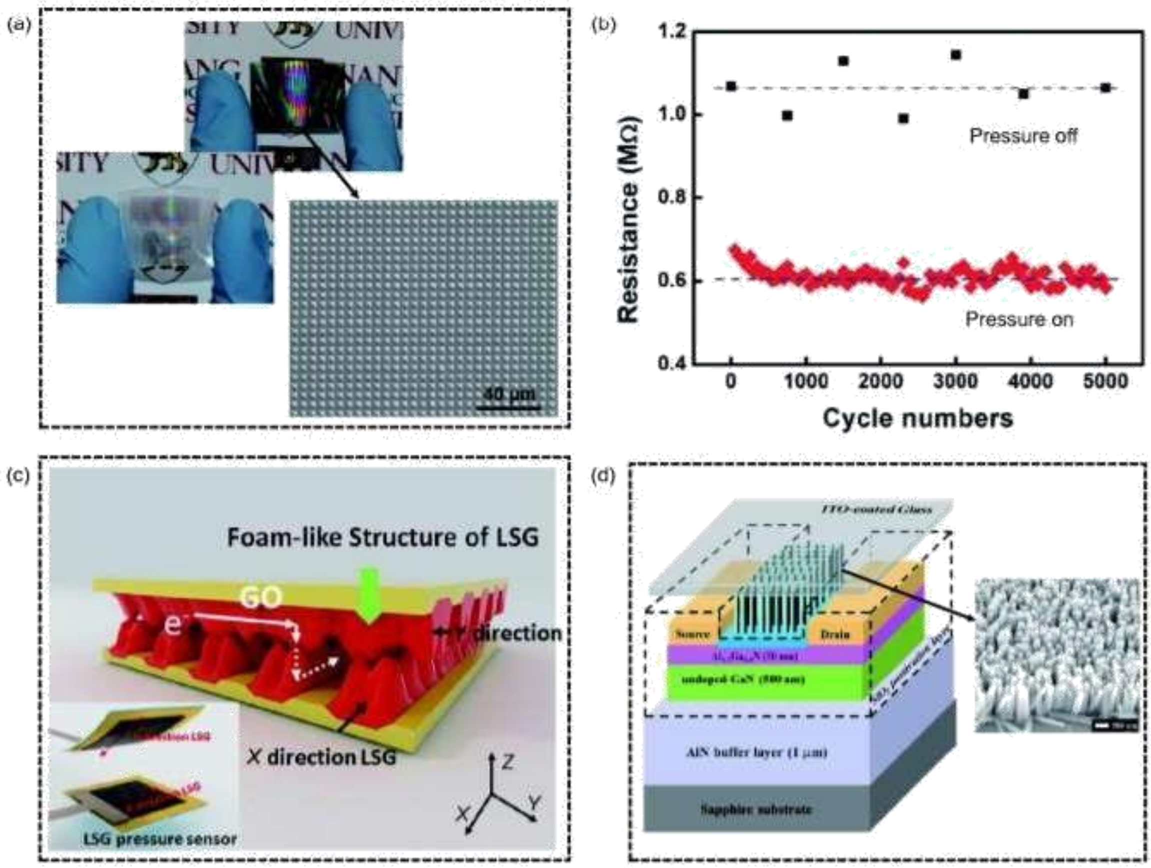
Capacitive proximity sensors are non-contact devices that can detect the presence or absence of virtually any object regardless of material. They utilize the electrical property of capacitance and the change of capacitance based on a change in the electrical field around the active face of the sensor.





(a) Pressure-sensitive structured PDMS films and the microstructured details.
(b) pressure-response curves for different types of microstructured PDMS films .
(c) schematic of the fabrication of GO foam-based pressure sensor arrays.
(d) pressure response of GO foams with different densities .

After years of extensive development, flexible pressure sensor arrays are being widely applied in human healthcare and medical diagnostics, such as blood pressure, intraocular pressure, and pulse, which are significant health indicators. These sensor arrays have high resolution and rapid response beyond human perception. In particular, a stretchable pressure sensor was fabricated by employing PDMS arrays with spring like compressible platforms.



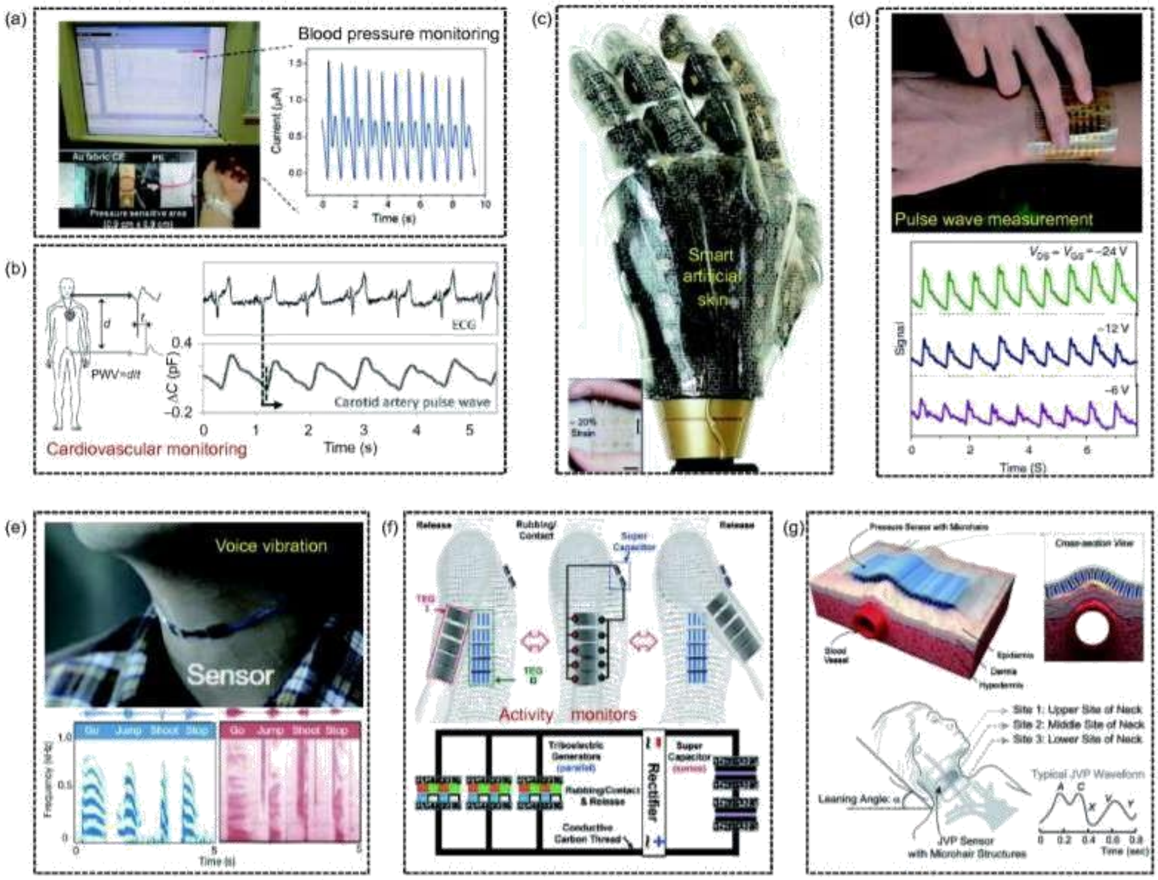
(a) Photos of the PDMS films with (top right) and without (bottom left) graphene layers and the pattern arrays;
(b) stability of the sensor under loading cycles;
(c) cross-bar device structure of the pressure sensor based on the foam-like LSG ;
(d) epitaxial structure, schematic configuration of the pressure sensors and the SEM image of ZnO nanorod array

Bioelectrical monitoring

Bioelectrical signals are now widely used for monitoring medical diagnoses and human activities. The conventional bioelectrical signals associated with the human body include **electrocardiograph (ECG), electroencephalogram (EEG), electromyography (EMG), and electrooculogram (EOG)**. ECG signal analysis is the most widely used strategy for the continuous and non-invasive diagnosis of different cardiac diseases and for assessing the physiological fitness of athletes . The conventional ECG signal acquisition systems generally consist of multiple biopotential electrodes that have extremely large contact impedances between the electrodes and the body skin. In the past few years, special attention has been paid to electrode improvements for obtaining better ECG signals . Particularly, new materials and new structural designs are being developed rapidly .

ECG:

The basic **principle** of the **ECG** is that stimulation of a muscle alters the electrical potential of the muscle fibres. Cardiac cells, unlike other cells, have a property known as automaticity, which is the capacity to spontaneously initiate impulses.



Some promising applications of pressure sensors. (a) Demonstration of blood pressure monitoring using a pressure sensor

(b) real-time transient signals of pulse-wave velocity recorded at the femoral and carotid artery .

(c) photograph of a representative smart artificial skin with integrated stretchable sensors and actuators .

(d) sensors attached to the artery of the wrist and the signals

(e) a sensor attached to the neck for recording human speech .

(f) schematic descriptions and the morphology of integrated energy devices .

(g) measurement of pulses on the identical contact sites of the neck .

Respiratory monitoring

In the past decade, various respiratory diseases, such as the sleep apnea syndrome, asthma, and chronic obstructive pulmonary diseases, have caused substantial problems to human health. Most respiratory diseases are chronic in nature and have a major impact on both the individual patients and the community. Information about the respiratory state is of great significance in several medical applications. In real life, most respiratory monitoring devices are designed to achieve long-term signal monitoring and disease diagnosis by integrating the various basic sensors mentioned above .

Many integrated electronic devices for respiratory monitoring have also been reported . In particular, a flexible projected capacitive sensing mattress composed of a multielectrode sensor array has been proposed for personal health assessment .Compared with the conventional respiratory monitoring system, this device can identify human gestures and motions during sleep. Respiratory flow is another physiological indicator and is usually measured by using the nasal cannula. Experiments were further conducted to verify the feasibility and effectiveness of monitoring and diagnosing respiratory diseases.

Recently, a wearable self-powered active sensor based on a **flexible piezoelectric nanogenerator** has been fabricated the structural details of this seThe self-powered sensor can be used to monitor human respiration, subtle muscle movements, and voice recognition devices. The electrical output signals exhibit good reliability and feasibility. Moeover, the respiratory symptoms can also be monitored, such as airflow, snoring, end-tidal CO2, esophageal pressure, and breathing humidity . It has become increasingly important to have wireless, non-invasive flexible devices for monitoring the real-time respiratory process; this provides sufficient information for early detection and diagnosis of diseases

Various respiratory monitoring devices and sensors.
(a)Thoracic volume variation during respiration and gesture recognition during sleep
(b)schematic of the flow sensor and the simulated exhalation and inhalation processes
(c)piezoelectric active sensor and the measurement of respiration rate

Hydration monitoring

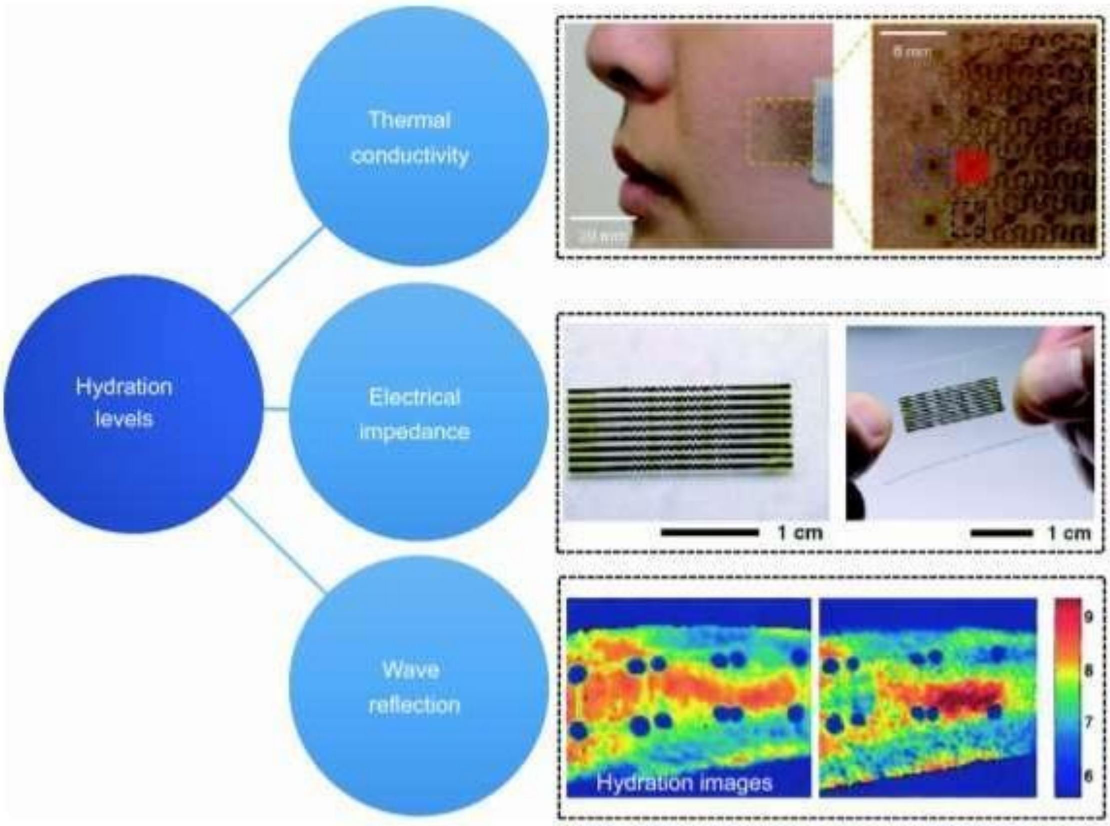
Skin hydration, which is another important indicator for analyzing diseases, can be characterized by measuring , Traditional skin hydration sensors rely on capacitive measurementsor impedance-based measurements in which the mechanical force is generally applied to a rigid electrode. The force compresses and deforms the skin thereby altering the capacitive properties and the hydration characteristics.

To measure skin hydration, electrical impedance provides the most reliable assessment. The basic principle of the impedance method is to bridge the correlations between the electrical parameters of biological tissues and their water content.

The epidermal electronic sensor adhered verywell to the various epidermises having different surface morphologies by using only van der Waals forces. Zhou et al.fabricated a gold nanoparticle-based colorimetricsensor to distinguish between dehydration and over-hydration using easily observable color changes, which were based on the principle that the gold nanoparticles allow colorimetric detection; the color of gold nanoparticles changes because of colloidal stability.

Sweat monitoring

To obtain more insightful information regarding human physiological indicators, various conformal chemical biosensors have been developed to noninvasively monitor biomarkers in human body fluids Many types of fluid biomarkers have been used as indicators for disease detection. For example, examining the cerebrospinal fluid can be useful for detecting the first onset of psychosis signature. Saliva is a readily available medium to be explored for health and disease surveillance. Scientific data has established the diagnostic value of saliva to detect diseases. However, persistent real-time disease surveillance requires continuous access to body fluids. Sweat, which contains tens to hundreds of compounds, plays a major role in the analysis of specific electrolyte concentrations.

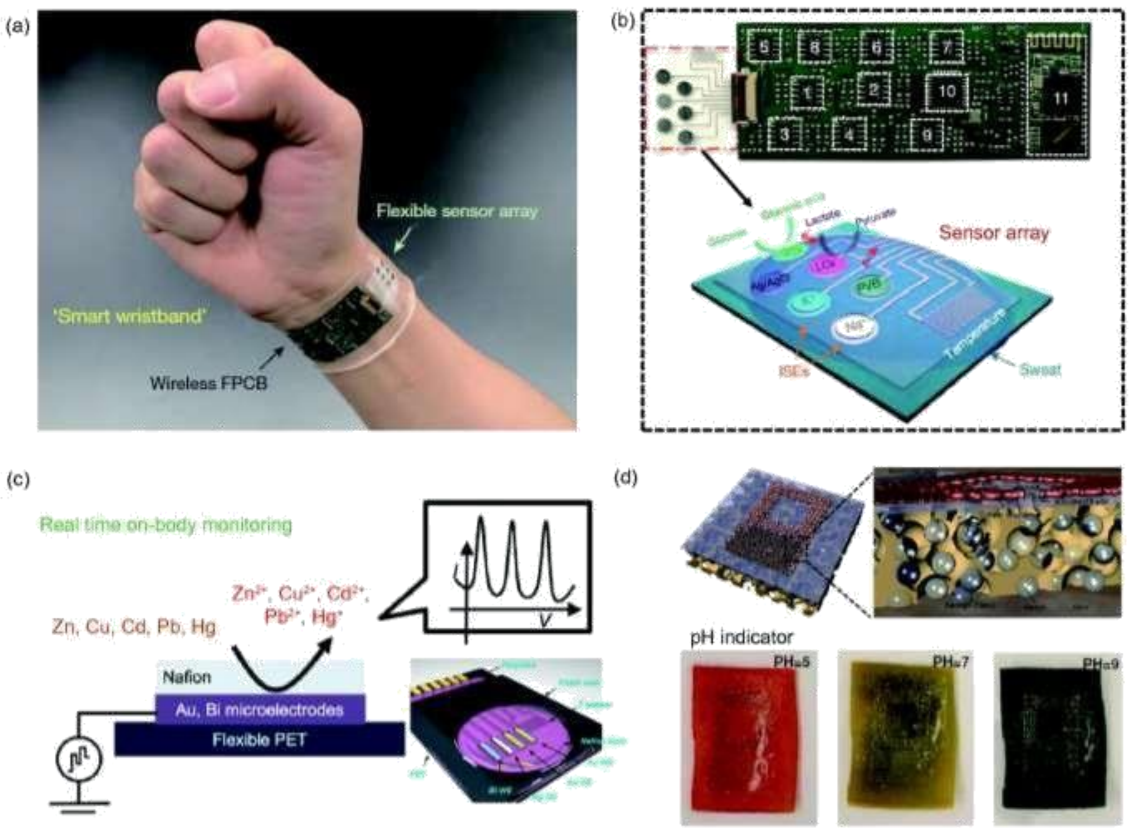


Typical methods for measuring skin hydration

Other multiplexed monitoring

Generally, human lesions are accompanied by changes in multiple physiological indicators. To improve the accuracy of human physiological signals, multisignal monitoring is being developed. In addition to the physiological signal indicators mentioned in the previous section, blood oxygen, blood glucose, and pulse are also important signals.

Using a comprehensive analysis of different signals , we can obtain more accurate physiological information. Recently, a multimodal sweat-based glucose monitoring device has been developed based on the integration of pH, temperature, and humidity measurements; this maximized the accuracy of the sensing



(a) Photograph of a wearable device integrating the multiplexed sensor array
(b) flattened flexible device and sensor array
(c) schematic showing the simultaneous multiplexed monitoring of heavy metals
(d) schematic illustration of a passive wireless capacitive sensor and the series of pictures of a sensor doped with a pH indicator

These electronic devices are of great significance for medical implants and environmental monitors because they are designed to be partially or fully dissolvable in ambient environment with controlled and predictable kinetics at predefined time scales.

MATERIALS USED

Silicon materials, though widely used in the traditional electronic industry, have limited applications in manufacturing flexible electronic devices due to the intrinsic inflexibility of silicon wafers and the complicated fabricating processes of its microstructure. Hence, searching for new and highly flexible materials as substitutes for traditional silicon material is of great importance. Numerous materials can be used to fabricate flexible electronic devices, such as graphene, carbon nanotubes, GaAs, liquid metals, conductive polymers and so on.

These materials can be divided into two classes: inorganic materials such as the traditional silicon and inorganic nanomaterials, and organic materials, which includes conductive polymers and electroluminescence organic molecules.

The low dimensional nanomaterials not only possess outstanding physical and chemical properties containing the merits of bulk inorganic materials, but they also have excellent intrinsic flexibility, so they are very suitable to manufacture the flexible electronic devices. Contrary to the inorganic materials, organic materials have outstanding intrinsic flexibility making them more suitable for fabricating flexible electronic devices, especially the large scale of display devices.

Nevertheless, organic materials also have some deadly weaknesses, which affect their development heavily. Compared with inorganic semiconductors, the conductive mobility of organic semiconducting materials is several orders of magnitude lower. The conductivity of inorganic metals is also several orders of magnitude higher than organic conductive polymers. The limited physical and chemical properties of organic semiconductors restrict the development of organic flexible electronic technology. But considering the industrial applications, the manufacturing process of organic materials is simpler than inorganic materials. Moreover, the manufacturing process of inorganic materials usually needs some corrosive chemicals, which are inconvenient and dangerous.

Inorganic nanomaterials

Two-dimensional (2D) materials

Graphene is a typical 2D material that possesses outstanding electrical, chemical and mechanical properties. As it is known to all, flexible electronics has a wide range of research areas. The applications using graphene in these areas include high-performance electric and optical devices, energy storage devices, and biological sensors. The transparent and flexible electrodes play a vital role in the electronic devices. The common commercial transparent electrode materials are indium tin oxides (ITO), while the rigid properties hinder the fabrication of flexible transparent electrodes. Because of the ultrathin feature, graphene possesses excellent light transmittance and flexibility. Meanwhile, it also has good electric conductivity, making graphene very suitable for manufacturing transparent flexible electrodes.

Graphene Oxide (GO) is manufactured to functionalize graphene using a strong oxidizer such as $KMnO_4$ to oxidize the graphene. Their work also had attractive applications in flexible charge-based memory devices such as dynamic random access memory (DRAM) and flash memory.

Aside from the graphene materials family, there are numerous other 2D materials which can be used in flexible electronic devices. Transition metal dichalcogenides are a class of 2D materials which have high carrier mobility, photoconductivity, thickness-dependent electronic band structure, and environmental sensitivity. Hence, they have better prospects for applying in electronics compared to other materials. Except transition metal dichalcogenides, **2D boron nitride** is also an important dielectric material which can be used to fabricate field-effect transistors.

One dimensional (1D) materials

Carbon nanotubes (CNTs) is a promising material for flexible electronics for their significant mechanical flexibility, conductivity and intrinsic carrier mobility, which can be used to serve as the channel materials in field-effect transistors, and also can be fabricated as films for transparent electrodes. Besides, CNTs is also a highly suitable candidate for other flexible electronic applications. Actually, many CNTs materials possess numerous defects, so pure CNT yarn in previous reports can bear only 7–8% strain as the fractures will appear when the strain increases to the maximal limit. In this case, some approaches were put forward to strengthen the flexibility and stretchability of the CNT yarns.

Except for CNTs, there are some other materials which also play important roles in flexible electronics. **Silicon** is a traditional material which is mostly used in the semiconductor industry. To solve the problem that silicon cannot be bendable and stretched, silicon nanoribbon material was invented to improve the flexible ability of silicon materials. For example, vertical aligned GaAs or InP nanowires can be grown with predepositing metal catalyst on GaAs or InP wafers via the VLS process.

Compared with metal materials, the conductivities of CNTs and conducting polymer materials are poor, which results in their limited applications and performance. In this case, metallic nanowires (NWs) have roused immense interest of researchers. To the best of our knowledge, most metallic nanowires research is focusing on seeking the substitutes of indium tin oxide (ITO), while only a few groups are studying the flexible electronic applications of metallic nanowires.

Organic materials

Polymers

Polydimethylsiloxane (PDMS) is the most common substrate material used in flexible electronic devices. Aside from PDMS, there are numerous other polymer materials which can be used in different aspects of flexible electronics. For instance, conductive polymers can be used for interconnects, and semiconductor polymers can be fabricated as organic transistors. Semiconductor polymers have a cost advantage over traditional inorganic semiconductors such as silicon which require complicated process technology and expensive equipment

Poly (3,4-ethylenedioxythiophene): polystyrene sulfonate (PEDOT:PSS) is a kind of water solution conductive polymer, which has great electric conductivity and is most widely used in the conductive polymer materials area.

Semiconducting polymers materials are other important candidates used in the flexible electronics field. They are intrinsically stretchable and can be manufactured using standard process methods. These properties make them very suitable for fabricating the film based field-effect transistors which can be applied to wearable electronic devices. Similar to conductive polymers, semiconducting polymers are also not stable when they are stretched or bent. The chains of normal polymers are easy to break when the polymers undergo large applied strains. So enhancing the mechanical stability of semiconducting polymers and even achieving the self-healing property have always draw the attention of researchers. Lots of semiconducting polymers are conjugated polymers. Usually, the conjugated polymers which contain modified side-chains and segmented backbones are infused with more flexible molecular building blocks to enhance the stretchable ability greatly.

Other organic materials

Aside from polymer materials, there are numerous other organic materials such as small organic molecules, organometallic complexes and so on**. Organometallic** complexes are a class of materials which contain lots of interesting electrical, optical and magnetic properties. The outstanding optoelectronic characteristics make these materials very suitable for making some luminance applications such as OLED which is a very promising flexible electronic display device. Partially OLED products with excellent performance have even achieved commercial targets at current industrial situations.

OUR IDEA:

To make " ***ZOLL LIFE VEST***"

Challenges faced:

- high cost
- very delicate
- needs advanced manufacturing techniques

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