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# Wearable sensing electronic devices with health monitoring function

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**Abstract.** Wearable mobile terminal (Wearable Devices) is a wearable mobile terminal that integrates sensors, wireless communication and multimedia technology into the human body. With the development of computer technology, wearable devices can perceive, record, analyze, adjust, intervene and even treat various diseases so as to maintain human health. Wearable electronic products refer to the intelligent exchange of information with the outside world using their own internal sensors and chips according to their physiological function or adaptability to the outside world. Wearable devices have been edging research in recent years, this paper introduces the characteristics of smart wearable devices, the materials currently applied, the different modes (types) of sensors, and discusses how the sensor network used for monitoring and transmitting recorded data can process the data network efficiently and accurately. In addition, as the sensor needs to consume more power to record and process the information obtained from the body, the battery life of smart wearable devices shortens. This paper summarizes some major concepts and methods related to the energy-saving of sensor components. Battery life significantly impacts the future personalization and universalization of health monitoring devices.

**Keywords:** flexible sensor, wearable technology, chip sensor.

## 1. Introduction

With the emerging need for health monitoring devices, more research has been carried out on wearable devices for health supervision. In this context, the research and development of intelligent wearable devices are increasingly valued. One of the earliest advances in sensors was monitoring the health of the human body. Later, with the progress and development of electronic science and technology, a wearable sensor was developed for continuous monitoring of the heart and pulse [1]. By wearing the device on different parts of the body, such as the head, eyes, wrist and so on, receptors in the wearable recognize the target analyte and respond accordingly. The sensor then converts the response of the receptors into useful signals that the user can use to take effective action. Such smart devices are expected to be applied in clinical and other areas of modern medicine [2]. But there are still some key problems with smart devices. If the rigid strength of the wearable device leads to the limitation of the wearer's activities, the material used in the equipment is of high quality so that users can not wear it for a long time. Also, due to a large amount of data processing tasks and the battery performance, the battery consumption is fast. The necessary features and functions of the designed smart wearable device could be determined by

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analyzing and understanding the user's requirements and opinions. For example, the flexibility of the device can be improved to match the user's motion state, and the weight of the device can be reduced so that people can move more easily. Further, the improved components, such as transistors and the analog-to-digital converter (ADC), can be used for remote travel. To meet the above mentioned performances, this paper reviews the current application of new materials in smart wearable devices, as well as advanced results in sensor circuit components. Finally, this paper summarizes the shortcomings and challenges of smart wearable devices in health detection.

## 2. Features of smart wearable devices

Wearable devices can provide information on body indicators. Intelligent wearable devices are machines fixed on clothes or directly in contact with the body surface, which can continuously and closely monitor the user's body condition and movement status. The body is in a sub-health state if the measured information has abnormal or irregular changes. Sensors play a decisive role in the process of measuring body indicators. The pulse can effectively monitor the heart rate, and the pressure, acceleration and strain sensors can accurately sense the pulse status. The electrode is a key component in acquiring electrical signals in the heart. The body temperature of the device wearer can be measured by more traditional methods such as pasted temperature sensor or infrared digital camera. As for the motion state of the human body, wearable sensors are worn on the knees and knuckles to detect the bending and stretching changes of the sensor strip caused by movement. This method is used in modern medicine to determine whether patients have abnormal tremors during movement [3]. This is a common method of examination in neurodegenerative disorders such as Parkinson's disease and ALS. At the same time, wearable devices are portable and easy to wear. The characteristics of the materials used often determine the portability of the device. Materials with lightweight, low density, with high tensile strength and toughness, can meet the requirements of wearers, such as poly (dimethylsiloxane) (PDMS), poly (ethylene terephthalate) (PET), polynaphthalene, polyimide, latex, etc., and has good performance in compatibility, bending, mechanical stability and temperature stability [4].In addition, carbon nanomaterials, which have been verified by experiments and can be widely used in wearable devices in the future, it has low density, high strength and good electrical conductivity. With the development of science and technology, carbon nanomaterials will certainly play an important role in flexible intelligent wearable devices.

## 3. Functional materials for intelligent wearable sensing devices

The materials used to make the sensors are determined by a number of factors, such as the application of the wearable device, its availability, and the total cost of manufacturing. Some commonly used sensor materials and their properties are described below.

### *3.1. Graphene*

*3.1.1. Methods for preparing graphene.* In 2004, the Geim team at the University of Manchester successfully isolated single sheets of graphene from graphite, each of which could be isolated from the surface of a highly oriented pyrolytic graphite sheet by using tape. In the laboratory, CVD is a common process for the preparation of graphene, which was first proposed in the 1960s. Its use is to prepare solid films with high purity and high performance. The principle of the chemical vapor deposition of graphene is that a gaseous substance containing carbon is passed into the furnace under high temperature and high vacuum, and hydrogen is used as a reducing gas [4]. The substrate surface of graphene is all deposited. Preparation of graphene in the tubular furnace by microwave plasma CVD device, radio frequency chemical vapor deposition, etc. (Figure 1).

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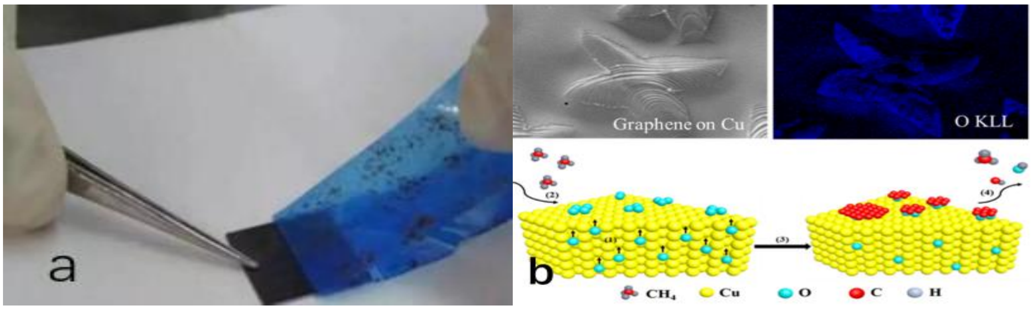


**Figure 1.** Methods for preparing graphene. a) Graphene was prepared by mechanical stripping; b) Single-layer graphene was prepared by CVD.

*3.1.2. Application of graphene in sensors.* Due to its excellent flexibility, biocompatibility and electronic properties, graphene has been widely used in sensors, including graphene mechanical and electrophysiological and fluid and graphene gas sensors [5]. Graphene mechanical sensors are often used to detect the user's breathing, pulse and movement, among which multilayer graphene and graphene-like sensors are the preferred materials because of their good piezoresistive effects. Graphene electrophysiological sensors are often used to detect and record electrocardiograms, electroencephalograms, and electromyograms. They play a vital role in examining and treating diseases in the medical clinic. However, this traditional method is not good for human health, and prolonged wearing may cause skin irritation and swelling [6]. Graphene is widely used because it is a dry electrode with good conductivity and ductility. In the human body, fluids, such as glucose, metal ions, and lactic acid, can be achieved in this way. The commonly used device architecture is a three-electrode and field-effect transistor (FETS) architecture, with graphene being used as a common electrode (WE) in the former and as a channel in the latter, with specific modifiers. The working performance of graphene gas sensors can be improved in graphene gas sensing devices because of their huge specific surface area. In gas-sensitive devices, molecular water donors are used to increase the concentration of electrons and holes and then regulate their electrical properties to realize the regulation of their resistance and capacity. By means of light, the interlamellar spacing is adjusted by moving between graphene sheets, causing a change in the transmission spectrum, which in turn would appear different colors at different humidity levels [5].

*3.2. Carbon nanotubes*

Carbon nanofibers are made up of millions of carbon nanotubes arranged in parallel. The fiber shows higher mechanical properties because of the combination of larger porosity and larger porosity. CNTs fiber is an excellent elastomer, so it can undergo a large degree of deformation [7]. These characteristics also will capable of meeting the basic requirements of textiles and knitting.

Producing carbon nanotube fibers with high efficiency is the key technology for its application in equipment. Several methods are used to prepare carbon nanotube fibers, including wet-spinning fibers from carbon nanotube solutions, stretchable nanotube forests, or floating catalytic chemical vapor deposition (FCCVD) reactions. However, the wet process involves complex nanotube dispersion and purification processes, which can easily cause structural damage to carbon nanotubes, so the dry spinning process has a broader application prospect. The dry spinning process preserves the new intrinsic characteristics of individual nanotubes, such as high electrical conductivity, has a large aspect ratio, high thermal conductivity and good mechanical properties. Control of the spinning process and growth environment, the structure and properties of dry-spun fibers can be adjusted, which broadens the application of fibers to various targets. Carbon nanotube (CNTs) fiber based on spinnable wood can achieve high-quality carbon nanotube (CNTs) fiber on spinnable wood without consuming a lot of catalysts, so it has a wider range of applications and lower cost because of its advantages such as uniformity and low doping amount (Figure 2) [8-10].

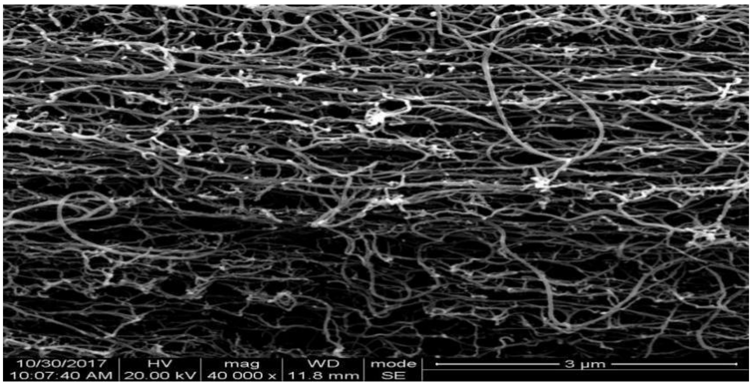


**Figure 2.** Industrial scale vertical array of multi-walled carbon nanotubes.

### *3.3. Metals and metal oxide nanowires*

The active component of a wearable tactile sensor could use metal nanowires. On this basis, the gold nanowire flexible pressure sensor has high sensitivity, G f higher than 1.14 kPa-1, fast response (< 17 milliseconds) and high stability (> 50000 times). Even a pressure of 13 pa can be detected [11]. Metal oxides are a kind of critical reactive substances in fields such as sensing. Because these reactions are carried out on its surface., and the nanowire has a high surface-volume ratio, the surface effect brought by the metal oxide nanowire can be well used to improve the working efficiency of the equipment. Recent advances in the production of metal oxide materials have made it possible to use them in devices with a wider range of functions.

## 4. Sensor function and power consumption optimization of wearable devices

### *4.1. Signal regulation*

The body signals collected by smart wearable devices are made up of analog signals with low intensity, low frequency and narrow bandwidth. These irregular, weak, and contaminated signals need to be amplified to increase the initial signal strength before subsequent components can process them. In wearable sensing circuits, transistors amplify signals. Among them, the classical transistor performing well in sensor equipment is the field effect transistor (FET). There are three terminals in the FET, including the source, gate and drain. The invention adopts a new structure, which separates the silicon dioxide on the gate electrode from the substrate so that a loss film is formed between the source electrode and the drain electrode due to the transmission of electrons and holes, and the effect of the loss film on the gate electrode is utilized to realize the regulation and control of the leakage electrode. In the wearable sensing system, the drain-source interface can be used as a biometric unit. The charge transfer caused by the change of analyte concentration will cause the change of gate voltage, and these differences will cause the change of leakage current, and then convert and amplify the chemical signal into an electrical signal [2].

This part of the power consumption optimization focuses on optimizing the transistor in the signal regulation equipment. In wearable sensors, large amounts of energy are consumed by amplifying circuits in order to amplify weak signals of interest. Therefore, the research on the wearable sensor amplifier circuit focuses on minimizing the power consumption without affecting the gain. A feasible solution is to reduce the loss in the amplifying circuit and keep its gain unchanged. The development of a Triode with high mutual conductivity can reduce the driving voltage and power consumption. For example, China, Romania, and so on. This project intends to study a kind of high-performance organic thin film transistor with extremely high trans conductivity. Through the study of the structure and performance of the device, the organic thin film transistor with extremely high transconductance is obtained. In this project, gold is used as the conductive layer, 2Magin9-dialkyl diol [2mag3-BGV 20j30f] and [3mae2b] thiophene as the channel layer, Au as the electrode and HZO/$Al_2O_3$ as the transport layer to construct organic thin film transistors [12].

### *4.2. Analog to digital conversion*

An efficient ADC that converts a continuous analog signal into a discrete number and minimizes additional noise. ADC performance is mainly affected by linearity and energy efficiency. The main ADC models are the flash ADC, successive-approximation ADC (SARADC), and Sigma-ADC [12]. Among them, SARADC and sigma-deltaADC are widely used. For these two types of ADC, two optimization methods are proposed here.1. Maximize the linearity of ADC without sacrificing the sampling rate and resolution.2. Effectively reduce its power consumption when the impact on its performance is not serious.

The most crucial component in cutting down on power consumption is the analog-to-digital converter. Switch mode and capacitive mode account for the majority of the ADC's power loss. In order to reduce the number of capacitors, the current effort focuses mostly on improving the circuit structure. This can be done by lowering the frequency at which switches and capacitors are currently used. Wang et al. suggested a BSSA bypass switching Synthetic SAR ADC based on dynamic proximity in response to the sparsity of ECG data. The common mode value can be found in the majority of the recorded ECG data. The previous MSB transformation stage can be skipped, conserving the switching power supply when the SARADC notices that the sampling signal is getting close to the common-mode level. To see if there is an input signal in a bypass window, the current value and the nearest neighbor comparison are first employed. Second, by charging at various rates at the Vbump and Vdiff nodes, the size of the bypass window could be modified. The bypass switch receives the input signal next. When the comparator input enters the bypass window in the first, second, third, and fourth stage transformations, the transformation will skip the second stage transformation and proceed directly to the sixth level transformation. In order to get all the binary code directly by omitting the MSB, a four-bit adder is used to perform the final operation on the first five-bit MSB. The BSSA circuit can improve energy consumption by more than 10% and energy consumption by more than 20%.

## 5. Conclusion and prospect

This paper focuses on the research status of wearable electronic devices. At the same time, with the development of new production processes and new production processes, the overall performance of the equipment continues to improve. Although significant achievements have been made in the field of smart wearable technology in the past, some major challenges in materials remain. Carbon nanomaterials, such as carbon nanotubes or graphene in the form of fibers, can only be made relatively easily in the laboratory to assemble various flexible components. However, large-scale production of macroscopic carbon nanomaterials has not been realized, and existing technologies are difficult to control their morphology. Safety is also an important issue, including the choice of flexible materials to ensure that the material is malleable and adaptable while the equipment is durable. And flexible batteries mounted on users face inherent limitations in electrolyte leakage, flammability and volatility.

## References

[1] Nasiri, S., & Khosravani, M. R. 2020. Sensors and Actuators A: Physical, 312, 112105.
[2] Liu, Z., Kong, J., Qu, M., Zhao, G., & Zhang, C. 2022. Biosensors. 12 889.
[3] Nag, A., Mukhopadhyay, S. C., & Kosel, J. 2017. IEEE Sensors Journal. 17 3949-3960.
[4] Feng, L., Jing-Long, H., Ji, Q. I., Zhang, Y., Jia-Luo, Y., Wen-Peng, L., ... & Bo-Wei, L. 2021. Chinese Journal of Analytical Chemistry 49 159-171.
[5] Qiao, Y., Li, X., Hirtz, T., Deng, G., Wei, Y., Li, M., ... & Ren, T. L. 2019. Nanoscale 11 18923-18945.
[6] A. J. Golparvar and M. K. Yapici. 2017. IEEE SENSORS. IEEE 2017 1-3.
[7] Lu, W., Zu, M., Byun, J. H., Kim, B. S., & Chou, T. W. 2012. Advanced materials 24 1805-1833.
[8] Li, Y. L., Kinloch, I. A., & Windle, A. H. 2004. Science 304 276-278.

DOI: 10.54254/2755-2721/23/20230650

[9] Behabtu, N., Young, C. C., Tsentalovich, D. E., Kleinerman, O., Wang, X., Ma, A. W., ... & Pasquali, M. 2013. Strong, Science 339 182-186.
[10] Zhu, H. W., Xu, C. L., Wu, D. H., Wei, B. Q., Vajtai, R., & Ajayan, P. M. 2002. Science 296 884-886.
[11] Yang, T., Xie, D., Li, Z., & Zhu, H. 2017. Materials Science and Engineering: R: Reports 115 1-37.
[12] Luo, Z., Peng, B., Zeng, J., Yu, Z., Zhao, Y., Xie, J., ... & Wang, X. 2021. Nature Communications 12 1928.