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Application Progress and Research Status of graphene materials in wearable sensors

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Abstract:

In this paper, the application status of graphene materials in wearable sensors was studied. Due to the excellent properties of graphene materials in mechanics, electricity, biocompatibility and other aspects, it has great hope to be used as wearable sensor materials, and play an important role in health detection, Internet of things and other fields. This paper summarizes the characteristics of graphene materials and the development and application of wearable sensors, expounds the advantages of graphene materials in wearable sensors, and introduces the application status of graphene materials in temperature sensing, heart rate monitoring and motion monitoring in detail. Then the bottleneck of graphene materials in wearable sensors and the problems to be solved are analyzed. Finally, the development prospect of graphene materials in wearable sensors is prospected, in order to provide some improvement ideas and future research directions. In conclusion, this paper provides an important reference for the further development of this field by studying the application status and bottleneck of graphene materials in wearable sensors.

Keywords: graphene materials, wearable sensors, application status, composite materials, development trend

1 Introduction

Graphene, an allotrope of carbon that is stable at room temperature, consists of a hexagonal honeycomb plane structure tightly bound by a layer of carbon atoms and belongs to an emerging two-dimensional material with many unique advantages in the field of wearable sensors. For one thing, graphene has excellent electrical conductivity. It is one of the best electrical conductors known, with high electron mobility and low resistivity, making it an ideal material for sensor electrodes. For another, the flexible and thin-film properties of graphene make it ideal for use in wearable sensors. Graphene is a two-dimensional structure made up of a single layer of carbon atoms, which is very thin and flexible. The lattice structure of graphene is very stable and can withstand large forces and deformation without damage. This allows graphene to maintain its stability over a long period of use without fatigue or fracture. Graphene has properties that can resist oxidation, corrosion and chemical damage, thus guaranteeing the long-term stability and reliability of wearable sensors.

With the advent of the intelligent era and the Internet of Things era, the sensor as an important component of the signal acquisition level has shown a trend of covering the whole field and large-scale use, and its development prospects are very broad, and the wearable sensor is a device that integrates sensors, processors and communication modules, and the sensor is worn on the human body or implanted in the human body. Can play a role in detecting physiological state and environmental information. In order to make it widely used in the fields of medical health, smart wearable devices and the Internet of things, wearable sensors should be as comfortable to wear as possible, stable and reliable and widely used, which requires that the transmittable sensor should have the characteristics of light weight, softness and low cost. Among them, the flexible sensor is the core detection part of the wearable sensor, the material and structure of the sensor determines the wearable comfort, detection specificity and corresponding sensitivity of the flexible sensor, and the introduction of graphene materials has brought new breakthroughs for the wearable sensor.

Therefore, the purpose of this study is to explore the application status of graphene materials in wearable sensors and the bottlenecks it faces. Through an overview of the properties of graphene materials, the development and application of wearable sensors, and the advantages of graphene materials in wearable sensors, it is helpful to further understand the potential and challenges of graphene in the field of wearable sensors. For example, in temperature sensing, graphene materials can realize the sensitive monitoring of small temperature changes in the human body, so as to achieve accurate temperature monitoring. In terms of heart rate monitoring, the high electrical conductivity of the graphene material allows the sensor to monitor the heart rate signal in real time and provide accurate heart rate data. Additionally, the graphene material has extremely high flexibility, which can prepare flexible sensors to adapt to the curve of the skin in different parts and improve the comfort of wearing. At the same time, graphene material also has high transparency, which can be used to prepare transparent sensors, making wearable sensors more hidden and easy to wear.

However, the reason why graphene materials have not been widely used on a large scale is that the current stage of graphene production and research is facing technical bottlenecks and challenges, such as high production costs, reliability problems and large-scale production challenges, etc. Therefore, we hope that the research in this paper will be able to contribute to the realization of technological improvement and innovation, multidisciplinary cooperation and cross-application, cost reduction and large-scale production, in order to provide reference and guidance for further research and application of graphene materials in the field of wearable sensors.

2. Development and application of wearable sensors

With the arrival of the 5G era, the concept of the Internet of everything has become possible, smart wearable devices set data collection, transmission and analysis functions in one, wearable sensors as an important part of the perception layer of smart wearable devices, rapid development in recent years, it integrates sensor technology into smart bracelets, smart watches, smart helmets and electronic skin, etc. Thus showing some physiological conditions of the human body. Due to the excellent characteristics of graphene, such as thin and transparent, wearable sensors made of graphene have the characteristics of portability, comfort and concealment, and are widely used in health monitoring, movement tracking, physiological status monitoring and so on.

First of all, wearable sensors can be used in the field of health detection, when the user wears the smart detection device equipped with wearable sensors, it can record the user's heart rate, blood oxygen and sleep and other physiological conditions, realize daily health detection, and provide relevant indicators and references for medical diagnosis and treatment. Secondly, the application range of wearable sensors continues to expand. In addition to the field of health monitoring, wearable sensors also have a wide range of applications in sports, entertainment, security and so on. For example, in the field of sports, wearable sensors can record athletes' posture, range of motion, strength output and other data, thereby helping athletes improve training results. In the field of safety, wearable sensors can be used to detect falls, falls and other unexpected conditions, if through wireless communication technology and family and first aid center linkage, family and hospital can respond in time, so as to quickly start first aid, care for the elderly, accident first aid and other aspects of great significance.

The related research of wearable sensors has great development potential. In the future, we can expect wearable sensors to show more application value in more aspects, and with the progress of technology and cost reduction, wearable sensors will be more popular and intelligent. However, there are still some problems and challenges in wearable sensors at present, such as the selection of materials, data accuracy and data security, which need to be further studied and solved.

3 The advantages of graphene materials in wearable sensors

Graphene has many excellent properties, in terms of mechanics, graphene is very strong, tougher than steel. It has an extremely high modulus of elasticity (1.1 TPa) and breaking strength (125 GPa), which allows graphene to maintain its structural integrity and stability over a long period of use. [1] Electrically, electrons in graphene can conduct freely, making it a superconducting material. Graphene is even more conductive than the metal copper, with electron mobility of (2,000 $cm^2 \cdot m^{-1} \cdot s^{-1}$). In terms of heat, graphene also has excellent thermal conductivity. The thermal conductivity of graphene is 2,000 times that of diamond, making it an excellent material for heat dissipation. Graphene is able to conduct heat rapidly, effectively transferring heat from the sensor surface to the surrounding environment to maintain the sensor's normal operating temperature. In addition to the above properties, graphene is also thin and transparent, flexible, and has excellent optical properties. These excellent properties make graphene an ideal material in the field of wearable sensors, which has also attracted wide attention and research.

Finally, graphene also has excellent chemical stability and biocompatibility. Graphene hardly participates in chemical reactions, is resistant to oxidation and corrosion, and has outstanding chemical stability, making it suitable for use as a sensing facility in complex working conditions. Graphene interacts very well with living organisms and does not cause allergic reactions or other adverse effects. This allows graphene to come into contact with the human body and enable effective biosignal detection.

4. The application of graphene materials in wearable sensors

4.1 Application of graphene materials in heart rate monitoring

Heart rate is an important physiological index reflecting the function of blood circulation. Accurate and timely recording of heart rate and other data can effectively prevent, treat and treat cardiovascular and cerebrovascular diseases. Therefore, heart rate sensor is an important field of wearable sensor application. Graphene materials show great potential in heart rate monitoring due to their unique properties.

Traditional heart rate monitoring techniques typically use electrodes to touch the skin to measure electrocardiogram signals or by measuring changes in the blood's absorption of red and infrared light. However, these methods have many disadvantages. Using electrodes for measurement will make the subject feel uncomfortable, complicated to use, limited by cost and location, etc. The use of infrared light for detection is often the use of heavy sensing equipment, will have poor wearing experience, easy to be affected by the environment and other defects. However, the emergence of graphene materials has brought new solutions for heart rate monitoring.

As an excellent new two-dimensional material, graphene is highly flexible and conductive. The application of graphene materials in heart rate monitoring has two main directions. First, graphene materials can be used to manufacture flexible heart rate sensors, and second, graphene materials can be used as electrode materials for sensors, because graphene is an excellent electrode material due to its high electrical conductivity, graphene electrodes can provide more stable and high-quality heart rate signals.

The selection of flexible materials is very important for the preparation of wearable sensors. Flexible materials can be more closely fitted to the skin, have less impact on daily life and sports, and can improve the use experience of wearable devices. Traditional silicon-based sensors are often large in size, low in flexibility, and not easy to fit the skin, resulting in poor wearing experience. Composite materials made of graphene materials produce certain structural changes during stretching, so that they can adapt to different shapes and fit different parts of the skin, making the sensor better contact with the human body. In addition, the graphene material also has ultra-thin and transparent properties, which can make the sensor more concealed and comfortable.

At present, there have been several studies exploring graphene materials for heart rate monitoring. Researchers have done this by preparing graphene films and using them to make heart rate sensors. Relevant experimental results show that the graphene material can effectively detect the human heart rate signal, and produce the corresponding waveform, after software analysis, you can accurately know the pulse data, with high sensitivity and stability.

4.2 Application of graphene materials in motion monitoring

In terms of motion monitoring, flexible wearable sensors are used as flexible stress and strain sensors, which can be used in the field of Internet of Things. Graphene, as an emerging nanomaterial, has shown broad application prospects in the field of wearable sensors.

First of all, flexible sensors made of graphene materials can be used in intelligent robots in motion monitoring. Operators wearing sensors remotely operate robots through 5G networks, which can complete tasks in harsh environments or perform remote surgery off-site. Traditional stress-strain sensors often use wires or metal connectors to achieve signal transmission, but these traditional materials have some shortcomings, such as low flexibility, too much weight and other problems. Graphene materials can be made into nanoscale films, which have extremely flexible and lightweight characteristics, and can better adapt to the state of human movement, thereby improving the accuracy and wearability of the sensor.

Secondly, the application of graphene materials in motion monitoring is also reflected in energy collection. With the increase of people's demand for wearable devices, the dependence on device energy is also becoming increasingly urgent. Graphene has excellent electrical and thermal conductivity and can be used as an ideal choice for energy harvesting devices. By combining graphene materials with thermoelectric materials, the thermal energy generated by the human body can be converted into electrical energy, which is used to supply the power demand of wearable devices, greatly extending the use time of wearable devices, and even is expected to replace the power supply equipment connected to the sensor, reducing the complexity of the device, and making it possible to miniaturize and miniaturize the sensor.

5 Bottleneck of graphene materials in wearable sensors

The main preparation methods of graphene materials are mechanical stripping, graphite oxide - reduction, chemical vapor deposition (CVD) and electrochemical methods, but the traditional preparation methods have problems such as high production cost, low reliability, and difficult to large-scale production.

5.1 Preparation of graphene by physical method

As an emerging material, the preparation process of graphene is relatively complex, requiring special conditions such as high temperature and high pressure, and the growth time of graphene is long, resulting in high production costs.

Since 2004, Geim of the University of Manchester in the United Kingdom proposed the use of tape stripping method to prepare graphene, and[1] then researchers have continuously used micromechanical stripping method, liquid or gas phase direct stripping method to improve the physical stripping method for preparing single layer graphene.

The micromechanical stripping method is similar to the preparation method proposed by Geim et al., using tape to strip highly oriented pyrolytic graphite (HOPG) to obtain graphene. Although this method can obtain high-quality single-layer graphene and the preparation method is simple, it is time-consuming and laborious, difficult to accurately control, and difficult to produce a large number of graphene products on a large scale.

Liquid and gas phase stripping methods are used to obtain single or multi-layer graphene solutions by means of ultrasound, heating or air flow. Coleman et al. dispersed graphite in N-methyl-pyrrolidone, and the yield of single layer graphene was 1% after 1h ultrasound, and increased to 4% after 462h[2] ultrasound. [3]Li et al proposed that by using high-temperature treated part of glass[4] graphite as raw material, intercalating with tert-butylammonium hydroxide, and adding DSPE-mPEG as stabilizer, monolayer graphene with a ratio of about 90% could be synthesized. Janowska et al. used ammonia generated[5] by decomposition of solvent ammonia water at high temperature to overcome the van der Waals force of the graphite lamella under high pressure, so that the graphite was stripped and monolayer graphene was made.

The above methods are generally simple to operate and low cost, but the quality of the products made is not stable enough, and problems such as impurities, defects, and more graphene sheets are prone to occur. At the same time, wearable sensors made of graphene often need to be combined with other materials to achieve a variety of sensing functions. However, compatibility problems between different materials can lead to unstable performance of sensors, which further affects the reliability of graphene materials.

5.2 Preparation of graphene by chemical method

Chemical vapor deposition (CVD) method to prepare graphene is to vaporize carbon-containing substances under certain conditions, and carry out a chemical reaction, and then deposit the product on a substrate made of a certain material to obtain graphene. This preparation method is now widely used in the semiconductor industry to prepare thin films, such as polysilicon and silicon oxide films.

If you want to prepare graphene by CVD method, it is mainly related to three aspects: carbon source, substrate and environmental conditions. At present, the carbon source of graphene growth is mainly hydrocarbon gas, mainly considering the decomposition temperature, decomposition speed and decomposition temperature of hydrocarbon gas, and the growth temperature is closely related to the selected carbon source. At present, the substrate is mainly used Ni, Cu, Ru and alloys. The selection of substrate directly affects the growth temperature, mechanism and product quality. Due to the large difference between the thermal expansion rate of Ni and graphene, the surface of the graphene product after cooling will appear a large number of folds. If single crystal Ru is used as the substrate, because single crystal Ru is expensive, and the combination with graphene is tight, it is difficult to transfer, which limits the further development and large-scale application of the method. If Cu is used as the substrate, according to the research results of N. P. Guisinger's research group of Argonne National Laboratory in the United States, the mono-crystal graphene islands nucleated on mono-crystal Cu have different orientations, resulting in the formation of defects at the lamellar junction, similar to the grain boundaries of three-dimensional materials [6]. If the quality of graphene is further improved, it is necessary to improve the preparation method, increase the size of the monocrystalline graphene islands and reduce the grain boundary structure. In short, the use of Cu substrate to prepare graphene is the best solution at present, but it still needs to be further improved in terms of cost control and stability.

6. Prospect of graphene materials in wearable sensor applications

At present, the application of graphene materials in wearable sensors has made some breakthrough progress, but there are still some challenges for technical improvement and innovation.

First of all, the technical improvement of graphene materials in wearable sensors needs to be considered from the two aspects of reducing production costs, expanding production scale and improving the stability and repeatability of graphene materials. Due to the special structure and properties of graphene materials, there are still some problems in the stability and repeatability of graphene materials in sensors. In order to solve these problems, there are still many researchers improving the traditional physical and chemical preparation methods and exploring other preparation methods, and constantly optimizing the production process to improve the quality of graphene products, we can use new preparation methods and material combinations in the future to improve the stability and repeatability of graphene materials.

In addition, as far as the specific application of graphene materials in wearable sensors is concerned, we also need to pay attention to its power consumption and integration. At present, wearable sensors are required to have the characteristics of low power consumption and high integration to meet the monitoring needs of long-term, easy to wear. Therefore, in the application of graphene materials, we can reduce power consumption and improve integration by optimizing circuit design and improving energy management methods.

The application of graphene In wearable sensors Is not limited to the progress of materials science to improve the production efficiency and quality of graphene, but also multidisciplinary cooperation and cross-application to achieve comprehensive and in-depth research content, bring innovative thinking and methods, and realize the cross-border application of graphene materials. It is believed that with the continuous deepening of multidisciplinary cooperation and the increase of exchanges between different disciplines, the application of graphene materials in wearable sensors will achieve more extensive and far-reaching development. For example, in chemistry, the performance of graphene materials can be optimized through the surface modification of graphene; In microelectronics, graphene sensors can be more miniaturized and integrated at the design level.

In addition, multidisciplinary cooperation and cross-application can also achieve better cross-border applications in wearable sensors made of graphene materials, expand the application field and scale, and attract more scientific research institutions and enterprises to carry out in-depth research cooperation. The graphene material wearable sensor will be extended to medical health, motion monitoring, smart home and other fields. For example, the combination of graphene sensors and biomedical technology can realize real-time monitoring of human health conditions; The combination of graphene sensors and smart home technology can realize the intelligent management of the home environment. The application range of graphene wearable sensors will be further expanded, attracting more research and development personnel in the industry to invest in the design and manufacturing of graphene materials, and finally promote the progress and development of the graphene material industry, and finally move to people's lives.

References

[1] Novoselov K S,Geim A K,Morozov S V,*et al.Electric* field effect in atomically thin carbon Control-insistent pang. Science, 2004306 (5696) : 666-669.

[2]Hernandez Y NicolosiV , Lotya M, e*t al*. High-yield production of graphene by liquid-phase exfoliation of graphite. Nat. Nanotech-nol., 2008, 3(9): 563-568.

[3] Khan U, O'Neill A, Lotya M, *et al*. High-concentration solvent exfoliation of eranhene. Small. 2010. 6(71: 864-871.

[4] Li X,Zhang G,Bai X, *Et a*l. Highly conducting graphene sheets and Langmuir – Ms. Blodgett control-insistent pang. Nat. Nanotechnol., 2008, 3 (9) : 538-542.

[5] Janowska I,Chizari K,Ersen O,*et al*.Microwave synthesis of large few-layer graphene sheets in aqueous solution of ammonia. Nano Res.,2010,3(2):126-137.

[6]Gao L,Guest J R,Guisinger N P.Epitaxial graphene on Cu(111)[J].Nano Letters,2010,10(9):3512-3516.