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# Application of Graphene Composites in Flexible Electrons

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**Abstract:**

With the development of science and technology, graphene materials have come into the public view, especially in flexible electronics and play a key role, which has attracted the public's attention. Because of its good electrical conductivity, high light transmittance and good flexibility, it has a high application value in the research and development of supercapacitors and epidermal electronics. This paper summarizes the structure and properties of graphene, discusses the application of graphene in supercapacitors and other aspects, describes the research progress and direction of graphene composite in flexible electrons in recent years, and the future development and prediction of graphene composite in flexible electrons. It is found that graphene has significant technical advantages and broad application prospects in the field of flexible electronics. The future prospects of graphene are still broad, and the joint efforts of scientific research and industry are expected to promote the further development and wide application of graphene technology.

**Keywords:** Graphene flexible; electronics; composite material

## 1. Introduction

With the rapid development of science and technology, flexible electronic technology has become one of the most innovative and promising application fields in the modern electronics industry.At the heart of this technology is the ability to make electronics that are both electronic and can bend, fold or even stretch, revolutionizing areas such as wearables, flexible displays, smart textiles, and biomedical sensors. Among many flexible materials, graphene has become an ideal material in the field of flexible electronics because of its unique two-dimensional structure, excellent conductance, thermal conductivity and mechanical strength.

Graphene, is a honeycomb plane material consisting of single-layer carbon atoms in a $sp^2$ hybrid orbit. Since its discovery in 2004, it has attracted much attention for its extraordinary physical and chemical properties.Its high electrical and thermal conductivity, as well as its high flexibility, as well as its almost transparent optical properties, give it great potential for applications in electronic devices. For example, a team from Zhejiang University developed a new type of graphene assembly film, which not only has excellent thermal conductivity but also is super flexible, can be repeatedly folded 6,000 times without breaking.This phenomenon shows the great potential of graphene to combine both high thermal conductivity and high flexibility in macroscopic materials. However, the high cost and difficult processing problems of graphene limit its widespread use in flexible electronics.To overcome these challenges, researchers began to explore recombining graphene with other materials in the hope of obtaining more cost-effective, easier processing, and better performance composites.By combining graphene with various polymers, metals, oxides and other materials, graphene composites can not only inherit the excellent properties of graphene but also adjust its electrical, thermal and mechanical properties through the design of composite materials to meet the needs of specific applications. The application of these composites in flexible electronic devices, such as flexible electrodes, sensors, energy storage devices, etc., has shown great potential and advantages.

This paper aims to explore the latest research progress of graphene composites in the field of flexible electronics, analyze their advantages and challenges in different applications, and explore their future development direction. Through the in-depth study of graphene composites, it is expected that the progress of flexible electronic technology can be promoted by us to bring more convenience and innovation to the human society.

# 2. Structure and Properties of Graphene

## 2.1 Structure and Properties of Graphene

Graphene is a two-dimensional crystal formed by carbon atoms in SP 2. The carbon atoms are arranged in a honeycomb lattice structure cell.In addition to the σ -bonded connection to the other three carbon atoms of each carbon atom, the remaining π electrons form delocalized large π bonds with the π electrons of the other carbon atoms, and the electrons can move freely in this region, thus giving graphene excellent electrical conductivity.At the same time, this tightly packed honeycomb structure is also the basic unit of constructing other carbon materials. Single atomic layer graphene can form zero-dimensional fullerene, and single or multi-layer graphene can curl to form single-wall or multi-wall carbon nanotubes.

## 2.2 Function

### 2.2.1 Good electrical conductivity

First, the electrical conductivity of graphene is mainly derived from the electronic structure of the carbon atoms. The carbon atoms have four valence electrons, while each carbon atom in graphene forms covalent bonds with only three surrounding carbon atoms, and the remaining valence electron is in a free electron state.These free electrons can move freely in graphene, forming an electric current. Because graphene is a single layer structure without gap width, its conductivity is very high.

Secondly, the electrical conductivity of graphene is also related to its special charged carrier transport mechanism. In graphite, the transport of the charged carriers exhibits a very special behavior due to the strong association effects and the zero-mass fermion properties.The charge carriers (electrons and holes) of graphite are described as Dirac fermions and move in a manner similar to relativistic particles, with linear dispersion relations. This particular transport mechanism gives graphene excellent performance in high-speed electronic devices.

### 2.2.2 The optical properties of the graphene field

The optical properties of graphene are first reflected in its transmission and reflection properties of visible light. Because graphene is a monolayer structure, its optical transmittance is very high, about 97.7%, which allows graphene to be used as an efficient transparent conductive thin film material. At the same time, the reflectivity of graphene is also very low, at about 2.3%, which means that it can effectively suppress the reflection loss of light.

The optical absorption properties of graphene then depend on the wavelength of the incident light.In the visible light range, graphene exhibits a very strong absorption rate of 2.3%, in sharp contrast to its extremely high transparency. In addition, the absorption range of graphene can be regulated through its regulation and thickness, which facilitates applications in fields such as optical sensors.

In addition, graphene also has a very high optical nonlinear effect. Optical nonlinear effect refers to a series of nonlinear optical phenomena, such as frequency doubling, mixing, etc.The nonlinear optical effects of graphene are mainly attributed to its special electronic band structure and charge transport law.This nonlinear optical effect allows graphene to show good optical properties in optoelectronic devices, such as high-speed modulators and optical switches.

In addition, graphene also has excellent optical heat resistance and optical stability.Due to its monolayer structure and tight arrangement of carbon atoms, graphene is able to maintain stable optical properties under high temperature conditions and is not susceptible to photocorrosion.

### 2.2.3 flexibility

Graphene is a two-dimensional material with excellent physical properties, which exhibits flexibility in many aspects.First, the small force of graphene's carbon atoms

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allows graphene to bend and deform without rupture when applying an external force. This characteristic makes graphene very suitable for flexible electronic devices.

In addition, the theoretical Young's modulus of graphene reaches 1 TPa with a fracture strength of 130 GPa, which is more than 200 times higher than that of ordinary steel, indicating that graphene is not only flexible but also extremely robust.The flexibility of graphene is also reflected in its processibility, which can be cut into specific shapes without the loss of its electronic properties, which is crucial for making applications such as micro-electronics and sensors.These properties of graphene, coupled with its excellent electrical and thermal conductivity, make it ideal materials for future high-tech applications.

## 3. Application of Graphene in Flexible Electrons

### 3.1 Supercapacitor

Supercapacitor is a kind of electrochemical element developed in the 1970s and 1980s. It is a kind of power supply with special performance between traditional capacitors and batteries.Compared with traditional capacitors and batteries, ultracapacitors have many outstanding advantages, including the durability of repeated charge and discharge, high power density and energy density, easy maintenance, small volume and large capacity, and the absence of heavy metal elements in the constituent materials, environmentally friendly, high-temperature reliability and high safety.

There are two main approaches in the current study to achieve flexible supercapacitors[1].A method processes the final product by using a flexible material or a high mechanical strength material as a material of supercapacitors.An alternative method changes the device structure to reduce the stress concentration by changing the device structure and maintaining a stable electrochemical output.

A stretchable isotropic buckling carbon nanotube film used as electrodes for assembling supercapacitors was reported by Yu et al[2].This carbon nanotube film has low resistance, all-directional high stretching, and repeated stretching electromechanical stability.Supercapacitors made with this film can withstand 200% omnidirectional strain, twice the maximum biweekly strain. Meanwhile, the capacitor's performance is increased to 1160.43 to 1230.61 mFcm-2.

A supercapacitor based on the highly stretchable and transparent electrode of an electrochemically stable Ag-Au core-shell nanowire percolation network was introduced by Lee et al[3].They developed a simple method for the synthesis of AgAu core-shell nanowires with excellent electrical conductivity, greatly improving the chemical and telephone first stability.Supercapacitors prepared based on core-shell nanowires can withstand up to 60% strain, and still have excellent light transmittance and excellent mechanical stability. Ag-Au core-shell nanowires can be strong candidates for future wearable electrochemical energy devices.

There are still some shortcomings in supercapacitors, such as the production cost is relatively high. In the future, supercapacitors will tend to improve the energy density, enhance the cycle life, reduce the cost and other directions.

### 3.2 Multifunctional Epidermal Electronics

The common electronic skin is mainly composed of two parts: flexible matrix and conductive filler.The appropriate flexible matrix can give the electronic skin the basic flexibility; secondly, the conductive filler and flexible matrix can provide the excellent telex sensitivity of electronic skin by ensuring the flexibility of electronic skin. Traditional electronic materials such as silicon, metal and oxide are limited in the practical application of electronic skin because of their large brittleness, so flexible materials or elastic materials are often used as the matrix for the construction of electronic skin, such as elastic film matrix, hydrogel matrix, 3D sponge matrix, etc.

Through the analysis and study of the microstructure of graphene, Ren's team established a theoretical model of crack with graphene ribbon structure as the basis, which better simulated the resistance value change process caused by stress.The multilayer graphene skin electronic skin can monitor the tiny deformation of the skin surface through the change of electric resistance, and measure the physiological signs such as breathing, heartbeat and voice by laying on the mask, wrist and throat, etc. The tester will not affect the normal activities when wearing.

### 3.3 Wearable Devices

There are many reports of graphene-based tactile / motion sensors. At present, the sensors developed for the characteristics of human wearing are flexible, deformable, and even pursue high sensitivity under high deformation.Other parameters have constraints on the sensor, such as short response time, response to more complex external strain, high behavioral resolution; good cycle stability, high sensitivity after multiple uses; high flexibility, and adaptation to the complexity of human action behavior.

The graphene-coated double-coated yarn developed by Sun Jing of the Institute of Silicate of the Chinese Academy of Sciences can not only achieve the sensitivity of 3.7 sensitivity factor, but also sense different external movements such as stretching, bending and rotation, which is used for the behavioral feedback of small robots[4]; Ding Guqiao research group of the Institute of Microsystems of the Chinese Academy of Sciences has developed a sensor based on graphene/polymer fiber, with a sensitivity factor of 87 that can detect the deformation of 1 in 10,000, and can be woven into the fabric to detect tiny behaviors of the human body, such as blink and pulse[5]. At present, most fiber motion sensors are based on the principle of piezoresistance. Fiber capacitors tend to favor energy storage, and triboelectric / piezoelectric based wearable electronics are biased to mechanical energy collection, so as to provide energy for wearable low-energy electronics.The flexible behavior sensors of graphene-based self-energy materials are mainly based on the composite with piezoelectric materials or triboelectric materials.Usually the piezoelectric material itself has the piezoelectric effect and can sense the external pressure. At present, a large part of the pressure sensors on the market are based on piezoelectric materials, but the detected piezoelectric signal is instantaneous signal, unlike the resistance / capacitive motion sensor, to achieve steady-state monitoring.To this end, the research group of James Xu of the Chinese University of Hong Kong developed a heterojunction pressure sensor based on high-quality graphene and piezoelectric PbTiO3 nanowires based on CVD growth.They used the dipole polarization caused by strain in piezoelectric nanowires as the working mechanism of charged impurity to affect the graphene carrier mobility, and prepared a pressure sensor with steady-state sensing external pressure, whose sensitivity can reach 9.4 103 kPa 1 and the response time is shorter than 5-6 ms

## 4. Conclusion

Graphene has an amazing strength and extremely high conductive performance, but also has ultra-thin, flexible, transparent properties, suitable for the manufacturing of flexible electronic devices.Graphene has a very high surface area and excellent chemical stability, which can achieve better electrochemical reactions and catalytic effects.As a two-dimensional material, graphene is widely used, including flexible sensors, capacitors, epidermis electrons, etc.

In conclusion, graphene has significant technical advantages and broad application prospects in the field of flexible electronics.With the continuous progress of technology and the reduction of cost, the application prospect of graphene composite materials in the field of flexible electronics will be even broader.In the future, the application of graphene composite materials in more high-tech products will be seen more and more, thus promoting the innovation and development of the entire electronics industry.

## References

[1] Xu Jianxin.Preparation and application of patterned flexible supercapacitors[D].Northeastern Electric Power University,2024.

[2] HONG J Y, KIM W, CHOI D, et al. Omnidirectionally Stretchable and Transparent Graphene Electrodes ACS Nano, 2016, 10(10): 9446-9455.

[3] LEE H, HONG S, LEE J, et al. Highly Stretchable and Transparent Supercapacitor by Ag-Au Core-Shell Nanowire Network with High Electrochemical Stability. ACS Appl Mater Interfaces, 2016, 8(24): 15449-15458.

[4] Cheng Yan, Wang R. A tenchable and highly sensitive graphene-based fiber, For the sensing of tensile strain, bending, and torsion. advanced material.December 2,2015;27(45):7365-71.

[5] Liu. M, Pu. X, Jiang. C. Y, Liu.T. X. Graphene-based triboelectric nanogenerator for self-powered wearable electronics, Adv. Mater. 2017, 29, 1703700.