

## Research on graphene and its application in touch screen

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**Abstract.** Graphene is a two-dimensional nanomaterial formed by the hybridization of carbon atoms. Graphene has become a popular new material in emerging industries because of its high conductivity, high toughness, high strength, high transparency, large specific surface area and other excellent properties. In view of the excellent properties and potential application value of graphene materials, a series of important progress has been made in semiconductor devices, transparent displays, sensors, capacitors, and other aspects. Graphene film light transmittance and conductivity is close to it ITO material, and can well solve the bottleneck of touch screen transparent electrode technology. It is one of the materials that replace Indium Tin Oxide (ITO) in flexible displays. Therefore, systematic research on graphene will play an important role in promoting the development of science and technology in the future. In this paper, the structure, properties, and development status of graphene are analyzed. Three traditional methods for preparing graphene films: mechanical peeling, chemical peeling, and chemical vapor deposition, and three novel process preparation methods: rotary spraying method, Plasma Enhanced Chemical Vapor Deposition (PECVD) method and layered self-assembly method are introduced. It summarizes the production process of graphene touch screen: transfer, modification, graphical, capacitive screen module preparation, its latest progress, and existing problems. Although preliminary studies have been conducted on the application of graphene films in various fields, the feasibility of its application has been verified, and it is expected to have significant advantages in some application fields, most of them are in the early stage of research and still face many technical challenges.

**Keywords:** graphene; structure and properties; application; preparation method; touch screen

### 1. Introduction

According to data, 60% of the world's patents now come from China. With so many patents, China's research and development in the field of graphene has obviously been in the leading position in the world. Moreover, according to experts, graphene, as a new material, can lead a technological innovation in China. Therefore, China's patent strategy in advance in the field of graphene will obviously play a great role in promoting the development of science and technology in the future. Graphene film has a wide range of applications in the fields of electronics, photons, and optoelectronic equipment. It can replace ITO as a new electrode layer to make graphene flexible display [1]. This new display has good mechanical properties and light transmittance, so it has stronger toughness and resolution, which can greatly accelerate the progress of China's electronic industry. This paper mainly introduces the new applications of graphene in flexible electronics, briefly summarizes the development status of graphene, and the preparation methods of graphene films. There is still a big gap between China and western developed countries in some high-end manufacturing industries, such as semiconductors, chips, lithography machines and other fields. Therefore, it is very important to develop graphene film technology [2]. These technologies are monopolized by western developed countries, and graphene technology can indeed break the key to

this dilemma. Therefore, the leadership of graphene technology can help China realize curve overtaking in the field of science and technology in the future. The research of this paper provides a theoretical basis for this transcendence.

## 2. Development and Application Of Graphene

### 2.1. Development of graphene materials

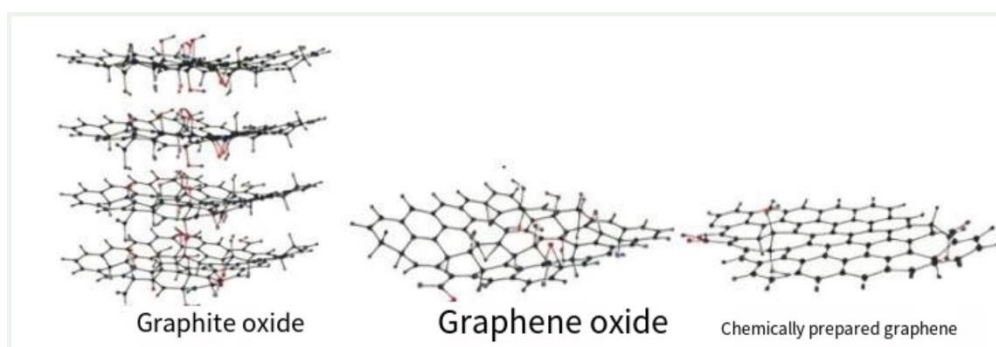
Since its discovery in 2004, graphene has been used in many fields [3]. Graphene is a single atomic layer of two-dimensional carbon nanomaterial, in which carbon atoms are covalently bonded to each other in a honeycomb lattice structure. It has long been thought that two-dimensional materials with single atomic layers are unstable and therefore impossible to obtain in nature.

Graphene can be divided into two categories: graphene powder and graphene film.

At present, graphene powder is the most studied, and its preparation and application have been systematically studied [4], and some achievements have been made. For graphene films, the preparation technology is the most studied. Although preliminary studies have been conducted on the application of graphene films in various fields, and the feasibility of its application has been verified, and it is expected to have significant advantages [5] in some application fields, most of them are in the early stage of research and still face many technical challenges. Because there is a big gap between the performance of graphene films prepared and the theoretical performance, researchers need to improve the preparation technology on the one hand to improve the performance of graphene films; On the other hand, combined with the characteristics of graphene, select the application field with significant advantages for in-depth research, and design product devices that can reflect the performance advantages of graphene film.

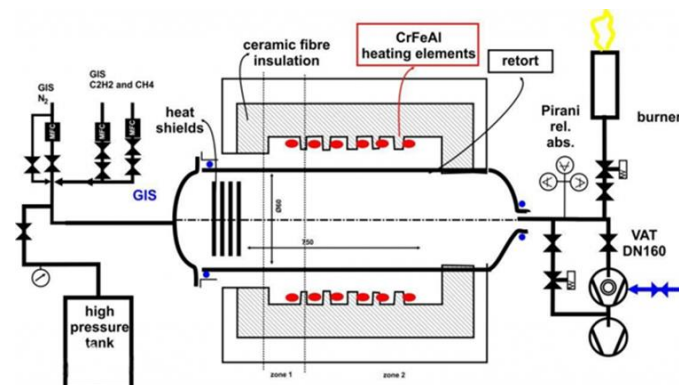
There are three main methods [6] to prepare graphene: mechanical stripping, chemical stripping, and chemical vapor deposition.

Mechanical stripping method mainly refers to the mechanical stripping method, which breaks the Van Der Waals force between the whole material and the graphite layer by mechanical force or ultrasonic wave, and strips the nanosheet layer from the main body layer by layer and then transfers it to the Si sheet. And mass production of graphene can be achieved by using ultrasonic assisted liquid phase stripping technology. Chemical stripping method mainly uses a strong oxidant and acid to oxidize graphite to go, and then uses a reducing agent to reduce the oxygen-containing groups on its surface to obtain reduced graphene.



**Figure 1.** Chemical stripping process

Chemical vapor deposition method [7] Single or multi-layer films are deposited on the surface of various materials or products by the reaction between gas phases. In gaseous condition, carbon compounds are used as precursors for chemical reaction, which are heated to decompose into carbon atoms and deposited on the substrate or catalyst surface to obtain graphene.



**Figure 2.** The process apparatus of vapor deposition

## 2.2. Development and application of graphene films

Graphene film can be applied to thermal conductivity film, play its excellent thermal conductivity, used for smart phones, tablet computers and other equipment heat dissipation layer; Graphene can be used to make flexible display screens, wearable devices, etc. Graphene has a large specific surface area and excellent electron transport performance. The transparent conductive layer in the display is the main use of indium tin oxide. ITO [8] also has some disadvantages such as difficulty in flexible displays. Perfect graphene film is close to ITO material [9] in light transmittance and conductivity.

The specific embodiment of the film [10] is shown as follows: blocking moisture into flexible display devices, reducing the effect of moisture on the display, and being flexible enough to bend at will; Light transmittance is very good, will not lead to inaccurate color display; High conductivity, can achieve ITO similar effect; Graphene is a carbon material, no pollution to the environment, in line with the requirements of green environmental protection. The use of graphene film as a touch screen is currently the focus of many companies in recent years. And graphene thin film touch screens have been mass-produced, as well as graphene capacitive touch screens.

## 3. Preparation of Graphene Film

The most important part of graphene application: graphene display screen is realized by graphene film. This chapter mainly introduces the preparation of graphene film.

### 3.1. Rotary spraying method

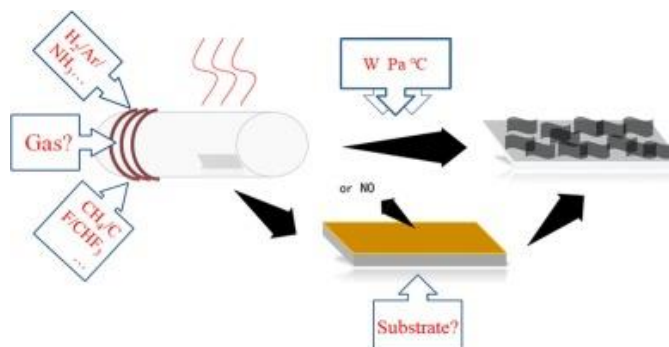
Graphene thin films were prepared by rotating coating in a certain concentration of graphene solution. Graphene dispersion is obtained by high-speed centrifugation, covered on the pretreated substrate surface, and graphene film is obtained by coating at an appropriate speed for a certain time. The thickness and quality of the film are affected by the number of rotations, external temperature, and humidity [11].

The graphene film prepared by this method has good flexibility and conductivity. Spin coating is a common method to prepare graphene films. The film prepared by this method is relatively uniform, the thickness is adjustable, and the method is simple. The film can be prepared on any shape of substrate, but the degree of rotation is most suitable for the solution with a certain viscosity. The selection of solvent has a great impact on the quality of the film [12].

### 3.2. PECVD method

Feldspar graphene films were prepared by PECVD. PECVD is a new process method to form plasma by glow discharge of process gas, activate chemical reaction and complete film preparation. RF PECVD process decomposes or ionizes the process gas into plasma gas under the action of RF electric field, which contains many positive and negative ions [13]. After these particles and free atomic groups continuously collide, diffuse and drift, they reach the sample surface and complete further chemical reaction, to quickly form the required preparation film.

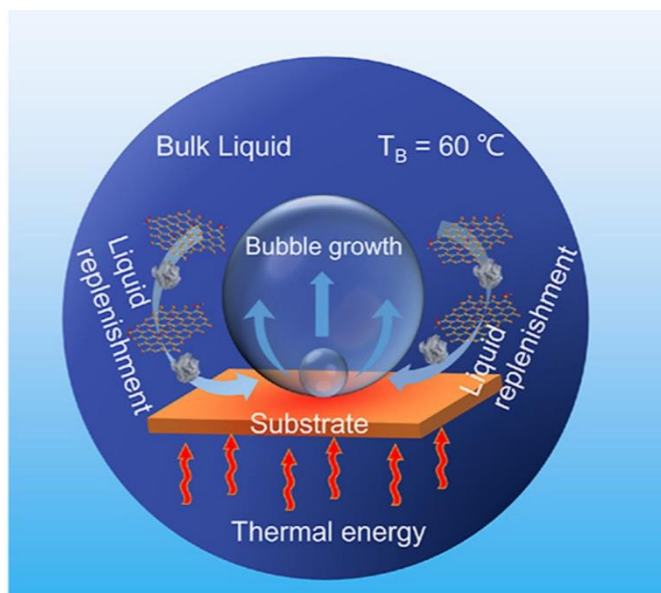
The advantage of using PECVD to grow graphene is that the plasma can activate the chemical reaction, so that the hydrocarbons can be cracked at a lower temperature, which not only reduces the reaction temperature, but also improves the film-forming rate. PECVD no longer completely depends on the catalytic cracking of carbon source on the substrate surface [14]. It can directly complete the preparation of graphene on insulating substrate, and omit the transfer steps of graphene on metal substrate to avoid the reduction of graphene performance in the transfer process [15].



**Figure 3.** Three elements for the preparation of vertical graphene by RF-PECVD method [16]

### 3.3. Layered self-assembly method

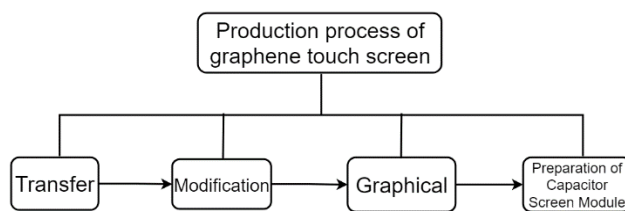
Layer by layer self-assembly method is a kind of layer-by-layer self-assembly method. To prepare graphene films, the surface of graphene oxide is usually modified to have different charges. Therefore, the self-assembled graphene film is driven by positive power, hydrogen bond, etc. The force has a significant effect on the morphology and structure of the films. Graphene film is prepared by layer-by-layer self-assembly method [17]. The restrictions of substrate type and size will not affect the graphene film. It can be prepared by controlling the structure and composition of the film.



**Figure 4.** Hybrid graphene oxide crumpled graphene film via subcooled boiling-induced self-assembly for highly efficient boiling heat transfer [18]

## 4. The Preparation Process of Graphene Capacitive Touch Screen

A high-quality graphene film is a transparent electrode with good performance to replace ITO as a capacitive touch screen. But it needs to be processed by the following steps: transfer, modification, patterning, and capacitive screen module preparation.



**Figure 5.** The production of graphene touch screen

#### 4.1. Transfer of graphene

Graphene grows on the surface of metal substrates, and it needs to be transferred to the target base for subsequent use. The existing methods include wet transfer, dry transfer, and transfer in non-atmospheric environment. This paper mainly introduces three methods:

##### 4.1.1 Based on PMMA sacrificial layer transfer method :

The surface of graphene is spin coated with PMMA, and copper is etched with acid solution. Then graphene is transferred to the target substrate, and finally PMMA is removed with acetone. However, during the transfer process, PMMA macromolecular particles are easily left on the surface of graphene film, which will lead to large leakage current and easy short circuit of the device. Therefore, before that, silver can be uniformly deposited on the surface of graphene by the reaction between silver ammonia solution and glucose [19] or adopt the “sandwich” transfer method, that is, the method of inserting small organic molecules (such as SPPO1) that are easy to wash off between PMMA and graphene film. It is easy to operate and widely used in the laboratory.

##### 4.1.2 Chemical etching transfer method:

Press the support layer (pyroelectric tape or PDMS) on the surface of graphene grown on copper foil etch Cu/Ni with acid or  $\text{FeCl}_3$  or  $(\text{NH})_4\text{S}_2\text{O}_8$  solution, and then attach the graphene/support layer to the target base. Finally, the PDMS film is removed by heating. The method can obtain a large area, and the shape of graphene can be cut by pyroelectric tape. And it takes less time. However, the etching solution pollutes the environment, and the etching base is difficult to recover, resulting in waste.

##### 4.1.3 Chemical etching transfer method [20]

Cellulose membrane transfer method is an aqueous phase transfer method developed by using the differences of substrate, nanostructure, and hydrophilicity of polymer membrane. This method can transfer nanostructures to curved objects such as microspheres. It has a great development prospect.

#### 4.2. Modification

The modification is to enhance the conductivity of the film while keeping the high transmittance of graphene. Under the condition of certain carrier mobility, the conductivity of graphene can be enhanced by increasing the carrier concentration of graphene through doping modification. Research [21] shows that nitric acid treatment will introduce doping into  $\text{sp}^2$  hybrid carbon materials and increase the carrier concentration, thus reducing the sheet resistance of graphene and improving the conductivity of carbon materials. The dopant has little influence on the lattice structure of graphene, and it still has high transparency.

Surface adsorption doping refers to the charge transfer between the surface dopant of graphene and graphene, which introduces additional carriers into graphene, improves the electrical performance [22]. A layer of nitrate ions is adsorbed on the surface of graphene nitrate, which significantly improves the conductivity of graphene. But the surface adsorption stability is poor, and under the heating condition, easily lead to nitric acid doping degradation.

Intercalation treatment is to insert different atoms or molecules into multi-layer graphene layers, and change the carrier concentration through the carrier migration between intercalation agent and graphene sheets, to change the mechanical properties. Using different intercalation agents can control

the electrical properties of graphene, and change its interlayer spacing, thermal [23].  $\text{FeCl}_3$  is often regarded as intercalation product because of its good stability. The film intercalated with  $\text{FeCl}_3$  has the characteristics of high transparency and low sheet resistance. When the intercalated film is applied to integrated circuits and flexible light emitting devices it shows good performance.

### 4.3. Graphics

Graphene is a two-dimensional nano material formed by hybridization of C atoms with  $sp^2$ . The chemical properties of C atoms are stable and it is difficult to etch with acid and alkali. Therefore, graphene patterning is a difficult problem for technical breakthrough. However, graphene is relatively thin, only one atomic layer thick, so useless graphene can be removed by high energy bombardment. C atoms can react with oxygen and other substances under special conditions; Therefore, we can consider etching graphene from these two aspects. The existing methods include laser etching and oxidation-reduction method [24]. The reducing agent used in the reduction method is N-diisopropylethylamine. And N-diisopropylethylamine is used as a reducing agent assistant, which is thoroughly reacted in a constant temperature water bath at  $100^\circ\text{C}$ . By reducing epoxy groups and other groups on the surface of graphene oxide, it can effectively reduce the surface, reduce the gap between graphene thermal conductive film layers and improve the usability of graphene transparent conductive film layers. After patterning, conductive silver paste is printed to enhance the film conductivity.

### 4.4. Preparation of capacitive screen module

The preparation of capacitive screen module is divided into: the front sensor process, that is the fabrication of graphene sensor, and the rear bonding process, that is, the graphene sensor and the touch chip are electrically connected and bonded the rough the flexible printed circuit board (FPC), and bonded with OCA optical adhesive under certain pressure and high temperature, and the cover plate is bonded to remove bubbles [25]. OCA optical adhesive is a special adhesive for bonding transparent optical elements. It has the advantages of colorless, transparent, light transmittance above 90%, good bonding strength, curing at room temperature or moderate temperature and small curing shrinkage [26].

In order to ensure the safety, a layer of PET electrostatic protective film is usually attached to the flexible cover plate to protect the capacitive graphene touch screen from static electricity through the PET electrostatic protective film, thus improving the use safety of the capacitive graphene touch screen.

## 5. Existing Problems and Improvement of Graphene Touch Screen

Graphene has broad application prospects in the field of touch screen because of its unique mechanical, thermal, optical, and electrical properties. However, there are still many problems in the generation and manufacture of graphene touch screen. The intrinsic carrier concentration of graphene is low, and the sheet resistance of graphene transparent conductive film prepared at present is too high to meet the practical application requirements. Therefore, it is very important to explore and improve the conductivity of graphene transparent conductive film to promote the application and development of graphene transparent conductive film. The adsorption of transfer interface impurities seriously affects the electronic transport characteristics of graphene, The actual uniform stacking size of materials is reduced, thus affecting the optical and electrical characteristics of transparent electrodes. Transparent electrode is an important factor that affects the performance of OLED devices. Therefore, the adsorption of interfacial impurities and the transfer of non-destructive large-area high-quality graphene films a still the bottlenecks and challenges faced by the transfer process. To improve the performance of related technologies and optimize the structure, it can save energy, protect the environment, and conform to the concept of sustainable development. In addition to the large area of graphene, how to prepare high-quality graphene films is still a hot issue.

## 6. Conclusion

This paper mainly shows the mass production of graphene through the research of some technical means in recent years and describes in detail the application of graphene in touch screen and the development of current technology. Graphene, as a material with excellent light transmission, electrical conductivity, flexibility, and chemical stability, plays a key role in various fields. By studying the preparation methods, graphene of different quality can be better applied in different fields. Continuous optimization and improvement of the production process to reduce the cost of graphene, to better play and application in the current electronic flexible screen. Three different methods of producing graphene in large quantities also determine their different cost and the final quality of the graphene. According to the properties of the graphene, complex processing is used to make the graphene touch screen. of course, the graphene touch screen has some problems because of its properties. Graphene is now widely used in mobile devices, aerospace, and new energy batteries. Graphene is a new generation of transparent conductive materials. The transmittance of four layers of graphene is comparable to that of traditional ITO films. The PECVD approach appears to be relatively favorable for future large-scale production of graphene. Graphene films and displays will also see greater breakthroughs in performance and applications as the technology is optimized.

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