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Advances in Properties and Applications of Graphene Composites Advances in Properties and Applications of Graphene Composites

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Abstract:

Graphene is a two-dimensional material with unique structure and special properties. Due to the excellent mechanical properties, antibacterial barrier properties and electrical conductivity of the composite material, it has been used in many fields. However, there are still some problems in the quality and properties of graphene composite materials. Currently,the main preparation methods of graphene composite materials are cold pressure sintering, electrospinning, solution mixing and solid phase synthesis, etc. The prepared composite materials mainly include graphene polymer composite materials, graphene-based inorganic nanocomposites, metal cornerstone graphene composite materials, etc. These composite materials have application value in the fields of anticorrosive coatings, electronic information, and medical materials. Therefore, this paper conclude the properties of graphene composites by summarizing preparation methods and composite material structures of graphene composites. At the same time, it shows application results of the graphene composites in anti-corrosion materials, electronic information field and the field of medicine.In order to provide reference for the performance improvement and innovative application of graphene composites in related fields.

Keywords: Graphene composites; two-dimensional material; medical materials; thermal conductivity composite; electrode material

1. Introduction

Graphene is a two-dimensional material which has attracted extensive attention in recent years,due to its uncommon two-dimensional hexagonal lattice structure.Graphene made up of carbon atoms bonded by sp2 hybridization, having a high electron mobility.With the deepening of research, graphene has become a research hotspot due to its unique structure, outstanding flexibility and barrier properties, good tensile strength, excellent hydrophobicity, antibacterial property, electrical conductivity, thermal conductivity and other remarkable properties.In addition, its application also gain wide attention, especially in anti-corrosion field and electronic information field. The properties and applications of graphene composites have also became a priority of research.The carbon polymer easily mix with graphene, due to the same atomic structure, achieving the ideal rigidity, toughness and heat dissipation.The addition of graphene polymer materials not only have a high mechanical properties, but also has excellent weather resistance, wear resistance, surface finishing, electrical insulation, acid and alkali resistance and water resistance. After the conductive polymer is effectively combined with graphene, the graphene sheet can be used as a scaffold material and conductive network. This not only significantly improve the specific capacitance value of graphene, but also improve the cycling stability of hybrid materials as electrode materials.

Furthermore, the current research on graphene composites is not only limited to graphene polymer composites.More and more attention has been paid to the application of graphene-based inorganic nanocomposites and graphene reinforcements in bulk metal-matrix composites. Specially, graphene-based inorganic nanocomposites can not only maintain the inherent properties of graphene and inorganic nanoparticles at the same time, but also produce novel synergistic effects, and have wide application value. As an ideal reinforcement phase, the composite of graphene and metal matrix can make up for the lack of pure metal in a single aspect, and has better performance than a single matrix.

However, there are still have some issues in the production field of graphene. For instance, the performance research of graphene composites is not deep enough, and the preparation method of graphene composites is not perfect. Especially, the quality of the prepared graphene is defective. In addition, the pollution caused by graphene during production process cannot be ignored.

This paper mainly reviews the preparation and properties of graphene and its composites, as well as the application research progress of graphene composites in related fields.

2. Preparation Method of Graphene Composite Material

Up to now, Graphene composites can be prepared by a series of methods, such as solid phase synthesis, vapor deposition, solution blending, sol-gel and thermal reduction.Each preparation method has different effects on the properties of different types of graphene composites.

In the cold pressing method, graphene and the composite matrix are first prepared into preforms by ball milling or pressure at room temperature, and then sintered at a certain temperature to obtain graphene composites.The sintering temperature can enhance to some extent of mechanical properties of composites. This method is commonly to prepare graphene/aluminum matrix composites and graphene/copper matrix composites. Electrospinning refers to the use of polymer solution changes in highfield to produce polymer fiber film. Therefore, it can make the graphene composite material have the advantages of large specific surface area, high aspect ratio and good flexibility without changing its own properties. This method is commonly used in the preparation of graphene and polymer composites, such as PU-RGO composites[1]. The solution blending method is to disperse graphene in the solvent, then add the matrix material for uniform mixing and remove the solvent. So that it can obtain the graphene composites with active groups connected to each other. This method is often used to prepare graphene gel materials. Solid-phase synthesis is a commonly used method for preparing graphene composites in the field of electronic information, which is generally used in the preparation of composite electrode materials. Wang Zhenting et al. prepared and analyzed carbon-coated lithium iron phosphate/graphene cathode materials with different graphene mass fractions which made by solid-phase synthesis method, exploring the influence of graphene fillers on the electrochemical properties of materials[2].

3. Structure and Properties of Graphene Composite

Multifunctional polymer composites made of graphene and other materials strengthen many special properties of the composite. Nowadays, the three most common composite materials are graphene polymer composites, graphene-based inorganic nanocomposites, and metal-based graphene composites.

3.1 Graphene Polymer Composites

Graphene polymer composite materials are composed of the polymer base,which is added an appropriate amount

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of graphene. Graphene overcomes the shortcomings of the common inorganic fillers, including dosage, the inability to take into account rigidity, heat resistance, dimensional stability and toughness, and improves the mechanical properties, thermodynamic properties and rheological properties of the polymer. The composite of graphene and polymer substrate can reduce the thermal expansion coefficient of the composite material and greatly increase the thermal conductivity.

Polystyrene has good processability, small molding shrinkage, low price, and wide application, but it is hard and brittle, and its heat resistance, mechanical properties and electrical conductivity are poorly performing. The polystyrene/graphene composites prepared by in-situ emulsion polymerization improve these shortcomings and improve their overall performance effectively.

After the composition of the graphene and the polyimide, the thermal stability, mechanical properties and electrical conductivity of the film will inevitably have a directional enhancement effect.At the same time, with the help of the perfect two-dimensional structure of graphene, it can have a certain planar induction effect on polyimide, causing a significant orientation effect on the surface of graphene, thereby easing the internal stress problem during the carbonization process of polyimide. At the same time, the fracture toughness of the carbonized product is improved, and the physical properties such as electrical conductivity are also improved.

Graphene has the advantages of large specific surface area, strong mechanical properties (Young's modulus can reach 1TPa), and good electrical and thermal conductivity. Graphene oxide contains a large number of carbonyl groups, carboxyl groups and hydroxyl groups, and can be well dispersed in water and alcohol solvents through intermolecular hydrogen bonds.A large number of studies have proven that both graphene and graphene oxide can greatly improve the oxygen barrier properties, mechanical strength and water resistance of polyvinyl alcohol (PVA) films, and can also make PVA films have certain electrical and thermal conductivity properties. This is of great significance for broadening the scope of PVA films.People often take surface modification of graphene or reduce GO to make it dispersed evenly in PVA with the help of intermolecular hydrogen bonds, thereby achieving nanocomposite modification of PVA membranes[3].

3.2 Graphene-based Inorganic Nanocomposites

Inorganic nanoparticles can also serve as important components of graphene composites. Since the presence of inorganic nanoparticles can increase the distance between graphene sheets to several nanometers and greatly reduce the interaction between graphene sheets, modifying graphene sheets with inorganic nanoparticles provides a new way to prevent the agglomeration of graphene sheets. From another perspective, graphene-based inorganic nanocomposites can not only maintain the inherent characteristics of graphene and inorganic nanoparticles but also produce novel synergistic effects, which have wide application value.

3.3 Metal Matrix Graphene Composites

As an ideal reinforcing phase, graphene also has wide application prospects in the field of metal matrix composite materials.Metal matrix composite materials can make up for the shortcomings of pure metals in a single aspect and have better properties than a single matrix. Most graphene/metal matrix composite materials have better strength, toughness, wear resistance and corrosion resistance than the original single metal.The tensile strength of the 0.3% graphene/aluminum-based composite material obtained by Han Yejin through powder metallurgy and hot extrusion is 2.6 times that of pure aluminum[4]. The wear resistance of the graphene-reinforced magnesium-based composite prepared by Zhang Liping et al. exceeds 80%[5].Graphene/metal matrix composites (Gr-MMC) have wide applications in aerospace, automotive, electronics and military fields.

4. Applications of Graphene Composite Materials

At present, there are two main ways in anti-corrosion applications of graphene. One is to act directly on the substrate, and the other is to use it as a nanofiller to modify the polymer coating. Using graphene in combination with polymer materials with anti-corrosion properties, and the comprehensive anti-corrosion properties of the prepared composite anti-corrosion coating are greatly improved. Utilize the characteristics of graphene's two-dimensional planar structure, nanometer thickness and impermeability, and combine it with resin materials to prepare coatings. The producting coating material has extremely high barrier properties and can effectively inhibit the penetration of corrosive media, which also has good corrosion protection properties. At the same time, due to the excellent conductive properties of graphene, it can meet many functional requirements.Polyaniline coatings have excellent corrosion resistance, because polyaniline can passivate metal surfaces. Polyaniline-doped graphene/polyaniline composite coatings can further improve the corrosion resistance of the coating. Polyaniline plays a role in shielding, corrosion inhibition and passivation in the coating, and can be used as a film-forming agent for anti-corrosion coatings. The ideal graphene composite coating has excellent physical barrier and obstruction properties which could protect the metal matrix.The composite coating does not have a self-healing function. Once the coating is mechanically damaged, it will soon lose its protective effect. It means that the coating only plays a passive protective role. How to increase the service life of the coating remains to be further studied.

Because of its unique honeycomb structure, graphene has the characteristics of high carrier mobility, conductivity, light transmittance, and strength. It can be widely used in manufacturing various electronic components. It is expected to replace silicon and become an important raw material for manufacturing new-generation semiconductor components. Therefore, the development and application of graphene composite materials in the field of electronic devices is currently a hot topic. Mix graphene with electrode materials such as metals, metal oxides, and conductive polymers to form composite electrodes. Graphene can be used as an electrode material for supercapacitors due to its large specific surface area, good flexibility, good mechanical properties and electrical conductivity. Zhang Xiaojuan prepared graphene/polyaniline composite materials through in-situ chemical oxidation polymerization and obtained different composite materials by changing the polymerization conditions. She used scanning electron microscopy, transmission electron microscopy, Raman spectroscopy, X-ray diffraction and other testing methods to characterize the materials, proving its excellent performance as a capacitor material[6].

Graphene has a large specific surface area which can carry more analytical molecules and provides more active sites. Its electron transport capability, sensitivity to the external environment, electrocatalysis of various redox reactions and chemical stability all have great application prospects. The large specific surface area of graphene makes it very sensitive to the surrounding environment, and can even detect the absorption and release of a gas molecule, so it can be used in the signal reception of chemical sensors[7]. Although research on graphene composite chemical sensors has made great progress, there are still many problems.At room temperature, the sensitivity of the sensor is much lower than that at high temperatures, and the detection environment is also subject to some limitations. Therefore, at normal temperatures, the sensitivity of the sensor needs to be further improved.

Graphene-based thermally conductive composite materials can be used as efficient thermal management materials for cooling high-power electronic devices. However, when flexible graphene nanosheets are assembled into macroscopic thermally conductive composites, during the solution-based spontaneous drying process, capillary force induces the graphene nanosheets to shrink inward to form wrinkles, thereby greatly reducing the thermal conductivity of the composite. This One glaring flaw still needs to be addressed.

The antibacterial ability of graphene allows its composite materials to be used to make various medical materials including graphene medical antibacterial bandages, medical gels, antibacterial coatings for orthopedic and dental implant materials, etc. For example, graphene medical antibacterial bandages can effectively promote the healing of skin wounds or surgical wounds. Bone graft materials can effectively provide antibacterial shielding while promoting cell proliferation at the transplant site, accelerating tissue and organ recovery. Graphene’s single-atom thickness and two-dimensional planar structure provide it with a huge specific surface area, allowing it to be used to load a large number of various molecules, including metals, biomolecules, fluorescent molecules, and a variety of drugs, making it have many potential applications in the detection, separation and purification of biomolecules and targeted drug delivery[8]. Functionalized graphene materials are expected to be used as drug carriers for controlled release and targeted control, and have good application prospects in the fields of biomedicine and biodiagnosis.

The physical, chemical, and biological properties of graphene and its derivatives point the way for future neural tissue engineering scaffolds. In addition, graphene oxide has a large specific surface area and oxygen-containing functional groups, which is beneficial to the adhesion of nerve cells, thus providing a stable environmental basis for the growth and proliferation of nerve cells[9].This is a feature that previous nerve scaffold materials did not have. Graphene and its derivatives and composite materials can promote the formation of functional microvessels, which is of great significance for the continued repair of neural tissue. Nonetheless, there is still some controversy regarding the biological toxicity of these materials, but at least based on the current research results, there is great hope that this issue can be resolved. In short, as a matrix of neural tissue engineering scaffold materials, graphene and its derivatives have shown unprecedented potential, but related research is still in the basic stage and there is still a long way to go before it can be put into practical application.

5. Conclusion

Graphene is a two-dimensional material with excellent performance and has unique advantages in several fields. At present, the main preparation methods of graphene composites include cold pressure sintering, electrospin-

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ning, solution blending and solid phase synthesis. Its composite materials have excellent electrical conductivity and antibacterial properties. Hence, graphene composite materials has application value in anticorrosion, electronic devices, medicine and other fields.In conclusion, graphene composites are fields with wide-ranging application prospects and research space.The prospect of graphene composite materials in the field of anticorrosion is mainly to comcombine with inorganic materials. So that it can reduce the additive amount of inorganic materials. In the field of electronic information, the main development direction of graphene composites is flexible electronic devices. Additionally, graphene composites show great potential in reducing antibiotic use in the medical field.

Based on this, graphene composites will develop differently according to the needs of different fields. However, the overall trend of graphene composite materials is to develop towards green, safe, lightweight, and technological. At the same time, the joint development of university scientific research and high-tech enterprises can also inject new impetus into the development of graphene composite materials.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

[1] Sun Yuan, Xin Yu, Tian Feng, et al. Progress in the application of biomedical polyurethane materials for tissue regeneration and repair replacement. Petrochemical Industry, 2024,53 (08): 1089-1097.

[2] WANG Zhenting, WANG Yankui, JIA Daozeng, et al. Graphene low zinc heavy-duty coating development. Journal of chemical industry of Guangdong province, 2020,(3) :3.

[3] He Yanyi. Preparation and properties of modified PVA nanofibers membrane research. Suzhou University, 2021.

[4] HAN. Y. J. Fabrication and microstructure properties of graphene/pure aluminum composites. Qilu Industrial University, 2024.

[5] ZHANG L P. Preparation and properties analysis of graphene magnesium matrix composites for sports equipment. The hot working processes, 2015, 44 (12): 3.

[6] Zhang X J. Preparation and electrochemical properties of high-quality graphene/polyaniline composites. Hunan University, 2024.

[7] Dong Junwei, Lu Yi, Liu Xia, et al. Research progress of graphene sensors and quantum dots Aerospace Metrology Technology, 2023, 43(5):47-51.

[8] Chen H H. Construction of biosensor and targeted drug delivery system based on DNA nanomaterials. Jiangnan University,2024.

[9] Hu S. The role of Iron-based materials in neural differentiation of stem cells. University of Jinan,2023.