Dean&Francis

ISSN 2959-6157

Improved Electrochemical Properties and Applications of Graphene Composites

Wenkai Wei

Manchester Metropolitan Joint Institute, Hubei University, Wuhan, 430062, China

Corresponding author: 21904293@stu.mmu.ac.uk

Abstract:

Graphene composites have significant advantages in improving electrochemical properties and applications. Graphene is an ideal material for improving electrochemical performance due to its two-dimensional structure, high electrical conductivity and large specific surface area. However, pure graphene still has some defects in electrochemical performance, such as agglomeration problems, interfacial problems, stability problems, and high production cost, etc. Therefore, the composite of graphene with organic, metallic and non-metallic materials can significantly improve the electrochemical performance and the thermal management of composites. The high strength properties of graphene also enhance the mechanical properties of composites and improve the tensile and compressive strength of materials. Compared with traditional materials, the low density of graphene can help reduce the overall weight of the composite material and improve its corrosion resistance. This paper compares these three composites in terms of improved electrochemical properties and explores the improvement of electrical properties to some extent by compositing graphene with these three materials. Finally, some applications of such composites such as batteries, flexible electronics and capacitors are also analyzed.

Keywords: Graphene composites; Graphene; organic materials; metallic materials; nonmetallic materials

1. Introduction

Among the large number of two-dimensional materials that have emerged in the last one to two decades, graphene remains one of the most promising, mainly because of its multiple excellent properties and its promising applications in different technological fields including biology, chemical sensing, biomedicine, photonics, electronics, and energy conversion and storage.Graphene is a single-layer, two-dimensional lattice structure formed by carbon atoms arranged in a hexagonal pattern. Graphene itself possesses extremely high electrical conductivity, one of the highest among all known materials. Furthermore graphene has excellent performance in electrochemical activity, double layer capacitance performance, electrochemical stability, flexibility and plasticity.

Although graphene has so many excellent electrochemical properties, it still has some shortcomings, such as its dispersion, controllability, cyclic stability, and its price cost is high. However, in order to optimize the electrochemical performance of graphene, researchers have compounded graphene with other materials to make up for the shortcomings of graphene and optimize its electrochemical performance. The researchers composite graphene with organic materials, metal compounds, and non-metal compounds to study the improvement of the electrochemical properties of graphene by the composite compounds.

This study evaluates the improved electrochemical properties and makes certain comparisons, and then analyzes these improved electrochemical properties for practical applications, such as in batteries, flexible electronics, wearable electronics, sensors.

2. Preparation of Graphene Composites

Firstly physical mixing method refers to the simple mixing of graphene with other materials such as polymers and carbon nanotubes to form composite materials.

Secondly chemical reaction method is also commonly used, which uses chemical reaction to combine graphene with other materials such as metal oxides and polymers to form stable composite structures through covalent bonding or non-covalent interaction.

However the chemical reaction method is to deposit graphene on the surface of other materials such as metal matrix, semiconductor to form a coating or composite film X.

In addition the self-assembly method is to utilize the self-assembly properties of graphene to combine it with other nanomaterials to form composite structures with specific functions.

Finally the solution method involves mixing graphene with other materials in a solution and forming composites after solution treatments such as solvent evaporation and heat treatment.

3. Improved Electrochemical Properties of Graphene Composites

3.1 Graphene Composite with Organic Matter

Graphene and polyaniline composites have improved electrochemical properties, and E-RGO-12 has a relatively stretched sheet, which provides a larger support surface for the subsequent in situ polymerization of aniline and improves the utilization of graphene [1].

The PANI network is tightly wrapped around the surface of E-RGO, forming a “PANI-(E-RGO)-PANI The PANI network is tightly wrapped around the E-RGO surface, forming a “PANI-(E-RGO-PANI)” layered structure, with the individual components connected by covalent bonds, which has a strong conjugation effect [1].The rough surface of the E-RGO/PANI composites and the pores in the PANI network are favorable for the electrochemical process, which increases the active sites for the electrode reaction, and thus improves the electron transfer rate [1]. In addition this composite is also very green and efficient.

Iodoacetic acid can participate in redox reactions in electrochemical environments and exhibit different electrode potentials. However, iodoacetic acid may decompose under certain conditions, leading to unstable electrochemical measurements. Nevertheless, graphene composite with iodoacetic acid can improve the electrochemical performance. The composites formed by graphene composite with iodoacetic acid have high structural quality, and the carboxyl groups on the surface increase the hydrophilicity and wettability of the material. The enhancement of graphene nanosheets by iodoacetic acid significantly improved the specific capacitance of graphene and the cycle stability of symmetric batteries.

3.2 Graphene Composite with Metal Compounds

Graphene and ZnO nanomaterials composite for improved electrochemical properties, G-ZnO nanocomposites synthesized by a simple one-pot method, which exhibit a unique folded structure with a high specific surface area of 143 m /g [2].

The high specific surface area is favorable for enhancing the capacitance and charge storage capacity of the electrode materials. The assay with 17β-estradiol exhibited a wide linear range of 0.05-100 M and excellent reproducibility, while repeated measurements performed by the researchers found that the RSD of graphene-zinc oxide composite nanomaterials was less than 3.5% [2].

Graphene and MnO2 composites improved the electrochemical properties, and graphene/MnO2 composites were prepared by growing MnO2 on the surface of graphene by water bath method. In addition, the addition of a two-dimensional material, black phosphorus, greatly improved the capacitive properties of this material, and from then on it had a high specific capacitance and the multiplication capacity was increased from 52.5% to 80.3% [3]. The application of this material to micro-supercapacitors can greatly improve the electrochemical properties of the composite material, thus proving the usefulness of this

ISSN 2959-6157

material.

3.3 Graphene Composite with Non-metallic Compounds

Graphene-based and hydrogel composite for electrochemical performance improvement, graphene nanosheets are doped into hydrogel matrix, while composite hydrogels of graphene have emerged as promising materials with unique properties. Various fabrication methods such as in situ reduction, physical mixing and chemical crosslinking have been used for graphene-based composite hydrogel composites to achieve well-dispersed and interconnected particle networks [4].

The resulting structures have high surface area, porosity and tunable pore size distribution, which is essential for applications such as adsorption, filtration and catalysis [4]. It is also characterized by high electrical and thermal conductivity and mechanical strength due to the addition of graphene sheets. The high thermal conductivity of graphene enhances heat dissipation, making it suitable for thermal management applications [4].

Graphene reinforcement improves the mechanical strength, stiffness, and toughness of hydrogels, enabling them to be used in load-bearing applications such as tissue engineering scaffolds and wearable devices [4].

However graphene composite with hydrogels produces materials that enhance their structural integrity, functional and mechanical properties.

Polymer composites with graphene nanomaterials have improved electrochemical properties, and polymer composites with graphene produce materials that bring improved stability due to the addition of graphene.

4. Applications of Graphene Composites

4.1 Batteries

A rechargeable zinc-air battery is a battery that uses zinc as the negative electrode and oxygen from the air as the positive electrode. This type of battery has a high energy density and a long service life. It generates electrical energy through the reaction of zinc with oxygen, and the process can be reversed when recharging to recombine the zinc with oxygen. The advantages of this battery include high energy density and environmental friendliness, but the challenge is to improve charging efficiency and cycle life. In addition, this battery uses graphene-Cu_2O as an air-cathode electrocatalyst cycle and excels in stability [5].

However, graphene also has applications in lithium-ion batteries. A lithium-ion battery is a rechargeable battery that utilizes the movement of lithium ions to store and release electrical energy. Because of their high energy density, long cycle life and light weight, these batteries are widely used in devices such as cell phones, laptop computers and electric vehicles. However, it still has deficiencies in these areas of conductivity, energy density, charging speed, and cycle life. The composite of graphene with lithium and silicon in batteries is conducive to further improving the overall performance of batteries, including conductivity, energy density, charging speed, and cycle life.

4.2 Flexible Electronics

Flexible electronics are those electronic devices that can be bent, folded or stretched. They typically use flexible materials (e.g., plastic, rubber, or film) as a substrate or conductive layer, which allows the device to adapt to different shapes and surfaces without damage. Flexible electronics are widely used in wearable devices, flexible displays, smart labels and medical sensors. However, carbon nanotubes and graphene are commonly used in flexible electronics, which in turn improves the thermal and electrical conductivity of flexible electronics [6]. Today graphene’s piezoresistive and piezoelectric sensing mechanisms have been used to create highly sensitive strain sensors for monitoring joint motion, muscle activity and respiration. And graphene-based pressure sensors in International Journal of Electrochemical Sciences 19 (2024) 100760 have been used in gait analysis, pulse wave monitoring and blood pressure measurement[7].

4.3 Capacitors

A capacitor is an electronic component used to store and release electrical charges. It consists of two conductors and an insulating material. When a voltage is applied to the ends of a capacitor, charge builds up on the electrodes, thus storing energy in the capacitor. Capacitors are widely used in circuits for filtering, coupling, decoupling and energy storage. Molybdenum disulfide/hematite/graphene ($MoS_2/Fe_2O_3/G$) composite heterostructures can be successfully prepared by hydrothermal method and can be used as electrode materials for supercapacitor devices.

The electrochemical performance of the prepared electrodes is superior to that of pure MoS_2 and MoS_2/Fe_2O_3 composites, and some researchers have shown that the device can maintain up to 77% of its capacity even after 10,000 cycles, thus the electrodes have significant capacitance and excellent cycling performance [8].Finally,ly graphene doping and Al doping can improve the electrochemical performance of cobalt phosphide to a great extent in addition to the morphological advantages. At an adjusted current density of 1 A/g, this new material recorded an excellent specific capacity of 312.3 mAh/g, which is relatively high compared to bare Al-CoxP, with a considerable capacitance retention of 87% (40 A/g). The solid-state asymmetric supercapacitor also exhibits excellent cycling stability (90% retention after 10,000 cycles) [9].

5. Conclusion

Graphene, as a promising two-dimensional material, is closely related to various aspects of human society, such as electronic devices, energy storage, sensors, composite materials, and flexible electronic products. However, there are still some deficiencies in the electrochemical performance of pure graphene, so we composite organic, metallic and non-metallic compounds with graphene. This optimises the graphene structure, increases the specific surface area, and improves the electrical conductivity to make up for its deficiencies in electrochemical performance and enhance its advantages in electrochemical performance.

However, this paper shows that most of the enhancement of electrochemical properties of graphene composites with organic and non-metallic compounds is due to the addition of graphene to these two compounds, while the materials formed by graphene composites with metallic compounds greatly improve their electrochemical properties due to the addition of metallic compounds.

Nevertheless, large-scale commercialization of graphene composites still faces a number of challenges, including high-cost production processes and standardization of materials.

However, with technological advances and improved production methods, graphene has a very promising future. With the advancement of technology, the production cost of graphene has gradually decreased, making its feasibility in large-scale applications greatly improved. New production methods will also promote the mass production of graphene. This material will find greater potential in electronic devices, energy storage, medical, and aerospace.

References

[1] Yapeng Wang, Yanxiang Wang, Yongbo Wang, Jianjun Liu,Facial preparation of covalent modified reduced graphene oxide/polyaniline composite and its stable-enhanced electrochemical performance,Heliyon,2023

[2] Yali Jiang, Yuning Song, Jiyu Yu, Chao Tong,Electrochemical detection platform based on graphene-zinc oxide composite nanomaterials for 17β-estradiol determination in milk,Alexandria Engineering Journal,2024

[3] Baocheng Liu, Zongsheng Cao, Zhengchun Yang, Wen Qi, Jie He, Peng Pan, Huayi Li, Ping Zhang,Flexible micro-supercapacitors fabricated from MnO2 nanosheet/graphene composites with black phosphorus additive,Progress in Natural Science: Materials International,2022

[4] Shokat Hussain, Shrikant S Maktedar,Structural, functional and mechanical performance of advanced Graphene-based composite hydrogels,Results in Chemistry,2023

[5] Barbara A.C. Sá, Tatiana S. Andrade, Rafael R. de Souza, Antero R. Santos Neto, Mariandry Rodriguez, Francisco G.E. Nogueira, Márcio C. Pereira, Rechargeable zinc-air battery with bifunctional electrocatalyst of copper oxide and graphene nanoplatelets, Electrochemistry Communications,2024

[6] Amirjalal Jalali, Mohamad Kheradmandkeysomi, Piyapong Buahom, Tanmay Gupta, Saeed Habibpour, Hosseinali Omranpour, Aiping Yu, Mohini Sain, Chul B. Park,Engineering lightweight Poly(lactic acid) graphene nanoribbon nanocomposites for sustainable and stretchable electronics: Achieving exceptional electrical conductivity and electromagnetic interference shielding with enhanced thermal conductivity,Carbon,2024

[7] Zengyu Ma,Advances in graphene-assisted flexible substrate sensors for human motion monitoring,International Journal of Electrochemical Science,2024,19

[8] Rajkumar Palanisamy, Diwakar Karuppiah, Sethuraman Venkatesan, Saravanan Mani, Madhan Kuppusamy, Senthilkumaran Marimuthu, Aravinth Karuppanan, Radhika Govindaraju, Sivakumar Marimuthu, Subadevi Rengapillai, Mozaffar Abdollahifar, Aswin Kumar Anbalagan, Ramasamy Perumalsamy, High-performance asymmetric supercapacitor fabricated with a novel MoS2/Fe2O3/Graphene composite electrode, Colloid and Interface Science Communications, 2022

[9] Emad S. Goda, Sang Eun Hong, Bidhan Pandit, Aafaq ur Rehman, Bal Sydulu Singu, M. Shaheer Akhtar, Muhammad Sohail, Salah M. El-Bahy, Heba Gamal, Kuk Ro Yoon,Metal-organic framework (MOF) templated hierarchical Al-doped CoxP @ graphene composite: A promising solid-state asymmetric supercapacitor with PANI derived carbon nanorods,Journal of Alloys and Compounds,2023.