Dean&Francis
ISSN 2959-6157

# Innovative Applications and Emerging Prospects of Graphene Across Various Fields

**Mengqi Cao**[1, *],

**Xiang Lou**[2]

[1]Shanghai Gold Apple Bilingual School International Department, Shanghai, 201208, China
[2] St. John's Senior School, North Lodon, Enfield, England

*Corresponding author: jialing.chiang@icloud.com

**Abstract:**

Graphene, a material formed by a single layer of carbon atoms, has emerged as a discovery which is a great breakthrough. It contains a wide-ranging implication for technology and science. Its remarkable properties make it an essential material in fields like electronics, energy, materials and biomedicine. In addition, it is also holding significant potentials for future innovations. In electronics, it enables faster, more efficient devices, while in energy, it promises to revolutionize solar cells and other renewable technologies. The high quality of dissipating heat that graphene has also make it significant for modern cooling systems, and in the biomedical field, its biocompatibility opens doors for novel treatments and diagnostics. The importance of studying graphene is clear, that it could fundamentally change how we approach sustainable energy, electronics, and healthcare, leading to advancements that affect nearly every aspect of the society. However, understanding its challenges must be vital, such as scalability and cost. While, as we focusing on its future applications, graphene research seems crucial for shaping the future of technology and science, and be able to produce a huge improvement for the development of the world.

**Keywords:** Graphene, structure, radiator, solar cell, onco therapy

## 1. Introduction

The fundamental building blocks of nanotechnology and nanoscience are called nanomaterials. While synthesized nanoparticles are quite interesting, certain nanomaterials have naturally occurring characteristics. Of all the nanoparticles used in engineering, carbon-based materials have attracted the greatest amount of interest thus far [1]. Their possession of a unique combination of physical and chemical features gives rise to this quality. Their contributions have been shown to be highly significant in a number of technological fields, including the energy sector. Due to their unique mechanical, electrical, optical,

ISSN 2959-6157

and magnetic properties that distinguish them from other particles, nanoparticles have found widespread use in the field of materials research. Moreover, they have found widespread application in biological fields, particularly the quickly expanding field of nanomedicine.

The current investigation offers a comprehensive analysis of the most recent advancements in the structural theory of graphene mechanics and its practical applications in daily life. The initial chapter provides a comprehensive analysis of the practical applications of graphene in the field of electronics. The second chapter primarily discusses the solar energy sector and other aspects of energy efficiency. This chapter investigates the utilization of graphene in a variety of materials, such as lubricants, as well as other related applications. The fourth chapter investigates the potential applications of graphene in the medical field for the targeted treatment of cancer under highly specific conditions, in light of its exceptional directivity.

## 2. Definition & Structure and properties

Because of its special qualities, graphene, a two-dimensional carbon atom lattice, has attracted huge attentions from scientists and engineers all over the world. Its intrinsic strength and conductivity, also with its atomic thinness, make it to be a strong material to apply a number of industries, such as computing and IT.

Graphene is known as carbon atoms firmly packed in a hexagon-shaped honeycomb lattice form a single layer, or monolayer. With a molecular bond length of 0.142 nanometers, it is an allotrope of carbon shaped as a plane of sp2-bonded atoms. Fig.1 shows the structure of graphene.

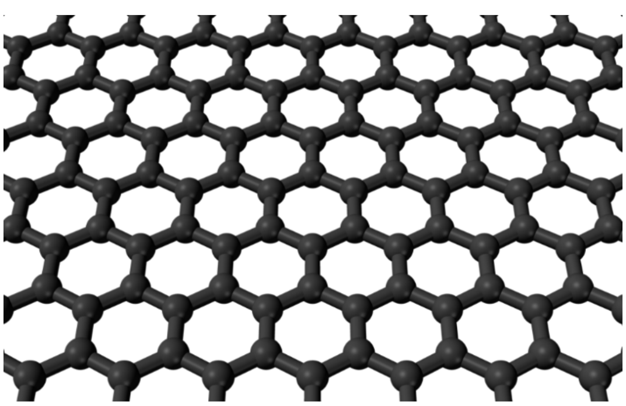

**Fig. 1 The structure of graphene sheet**

It is made by carbon particles, and they are connected by covalent bonds to form a sheet of graphene. Graphite is made up of layered graphene layers with an interplanar spacing of 0.335 nanometers. Van der Waals forces hold the individual graphene layers in graphite together, but they can be overcome when graphene is exfoliated from graphite.

The first use of graphite is the first pencil developed in 1560s. In 1900s, theoretical studies of graphene's electric properties had been discovered. Since 2000, freestanding graphene nano-membranes had been isolated, and graphene inks, transparent electrodes for solar cells had been discovered in one decade. After that, Inkjet-printed graphene electronics have developed in 2012, graphene flagship launched in 2013. Batteries and ultrahigh sensitive magnetic fields had added graphene in 2014 and 2015. It had then applied in parts of mobile phones in 2016. First zero gravity graphene experiments in collaborations with European space agency had been done in 2017. In 2018 and 2019, transmitter receiver and bioelectronic retinal implants started using graphene. In 2020, creation of world's first mass produced graphene-enabled solar farm [2].

Graphene is a highly resistant material so significant advancements in the lighting industry are anticipated, therefore it is also being an excellent electric conductor. Graphene applying in light bulbs, for instance, have the potential to extend its useful life of each globe and using less energy than using in the of LED lights with recent technologies. Graphene is a transparent material which only have a 2% to be visible and it also have only a very little light absorption. Because of its drastic flexibility, it is allowed to be produced flexible screens for a wide range of gadgets. Moreover, graphene is much less likely to break because it can be folded like cling film. It might be used in the production of automobiles, televisions, cellphones, and other items.

They also might be more durable and lighter than other materials in production of the drone batteries. Many scientists and researchers are trying to reduce the weight of these energy-accumulating components which might be a great innovation, therefore graphene considered to be hugely heavy in the technology. Because of greater phonon scattering on basic disadvantages and thermal coupling, supported graphene has lower thermal conductivity than suspended graphene, which could be more efficient with its intrinsic value.

Because of its unique electrical properties, graphene is expected to be able to transmit charge carriers at very fast speeds, which significantly speeds up calculations and data processing. For example, its zero-band gap makes the electrons in graphene can easily transform from the valence band to the conduction band using only little energy, which makes graphene to have an efficient charge flow, making it to be suitable for high-speed electronics devices. Furthermore, graphene also have an excellent internal energy efficiency good for reducing power usage, which is particularly significant in this energy-conscious society today [4].

## 3. The Application of graphene in different fields

### 3.1 Electronic field

Graphene's utilisation in the electronics industries. In the coming years, graphene has the potential to be utilised in a variety of electrical products, including displays. It is a highly promising substance. These technologies may include memories with large storage capacities, high-voltage distribution lines, implant sizes that are compatible with biological systems, and adaptable electrical devices. Additionally, it demonstrates a substantial electrical conductivity and a substantial degree of resistance, in addition to its translucency and flexibility. The primary factor that may assist scientists in the development of devices that are not only more cost-effective but also of superior quality is the thinness of this material. It is now possible to create devices that are more compact, lighter, more robust, and more efficient than those that were previously available by utilising this material. Graphene has the potential to achieve electron mobility exceeding 200,000 cm2/Vs under ideal conditions.

Graphene's exceptional performance is a direct consequence of its exceptional heat conductivity, which has been demonstrated in its ability to effectively dissipate heat during high-speed manufacturing operations. Effective heat regulation is considered to be a critical factor in the efficacy of high-power devices that employ graphene-based transistors. Additionally, it is capable of storing energy and generating electricity when exposed to light.

IBM has effectively developed transistors that can operate at frequencies of 26 GHz and 100 GHz by utilising graphene. Additionally, Samsung has created the Barristor, a silicon and graphene transistor that is specifically designed to facilitate the rapid and efficient transmission of information. Graphene is an ideal material for transistors that operate at extremely high frequencies (in the THz range) due to its exceptional mobility, which enables the rapid movement of electrons within the material. Graphene transistors have the potential to operate at a significantly faster speed than traditional silicon-based transistors as a result of this characteristic. Graphene possesses a number of exceptional qualities, such as enhanced flexibility, resistance, transparency, self-healing, self-cooling, and low resistivity, when contrasted with silicon. Additionally, it is capable of storing energy and generating electricity when exposed to light. Therefore, graphene has the potential to be particularly advantageous in applications such as microwave technology, high-speed amplifiers, and radio frequency (RF) communications. Copper's electrical and thermal conductivity are significantly lower than that of this material, which provides an additional advantage [4].

Walter de Heer, a research professor at the Georgia Institute of Technology, has invested in a cutting-edge platform that concentrates on graphene. The research team has successfully identified this distinctive quasiparticle. It may be feasible to manufacture computer processors that demonstrate improved environmental sustainability, reduced size, expedited speed, and enhanced efficiency in the future. The robustness of graphene's intrinsic chemical bonds is responsible for its capacity to maintain its two-dimensional structure. When it comes to silicon, it is possible to reduce its impact to a greater extent. They have the ability to increase operational efficiency and decrease heat generation in relation to those compact devices. A novel approach to electrical devices was introduced by a man named De Heer in 2001. This is dependent on the formation of a graphene layer on the surface of a crystal under its own favourable conditions. Additionally, it enables the utilisation of the unique characteristics of graphene in comparison to other materials in the electronics industry. De Heer anticipates that carbon nanotubes will undergo quantum disruption as the temperature plummets to such low levels, a property that silicon is unable to demonstrate at such low temperatures.

### 3.2 Energy field – solar cell

Amino silicon, gallium arsenide, and sulphuric acid are among the conventional semiconductors that have been extensively employed. Photovoltaic cells, which instantaneously generate holes and utilise liberated electrons in response to a photon, are examples of absorption. Nineteen Despite the fact that a power conversion efficiency (PCE) of over 40% has been attained. achieved for inorganic semiconductors (III–V) multijunction solar cells in the laboratory [5]. The utilization of inorganic solar cells remains widespread. restricted as a result of the obstacles associated with the modification of the bandgap of inorganic semiconductors and high expenses associated with the complex manufacturing processes that entail elevated temperatures and elevated hoover. Twenty-one These inorganic solar cells are still exceedingly expensive when contrasted with conventional electricity generated by the infrastructure [6]. Alternative methods that employ organic or polymer materials have been exposed to considerable attention as a result of their affordability cost, flexibility, portability, and solution processability.

ISSN 2959-6157

During photon absorption at ambient temperature, unconjugated polymers frequently generate bound electron-hole pairs, or excitons, in contrast to their inorganic counterparts. The dissociation of the excitons is therefore crucial for the generation of charge. This approach is acknowledged as advantageous at the interface of semiconducting materials that donate and receive electrons, but have distinct ionization potentials and electron affinities. the thirty-odd A typical active layer in polymer solar cells (PSCs) is composed of two materials, an anode and a cathode, which serve as donors and acceptors, respectively. It is imperative that at least one of these layers be transparent to allow sunlight to completely penetrate. As a consequence of the photoinduced charge transfer between the acceptor and the donor, electrons and holes are generated. When these particles are exposed to light, they migrate towards the cathode and subsequently accumulate at the anode. The integration of an electron extraction layer between the cathode and active layer and a hole-extraction layer between the anode and active layer is typically necessary in perovskite solar cells (PSCs) to enhance the electrodes' charge collection capabilities. [7]. The device architecture of a typical PSC is illustrated in Fig. 2.

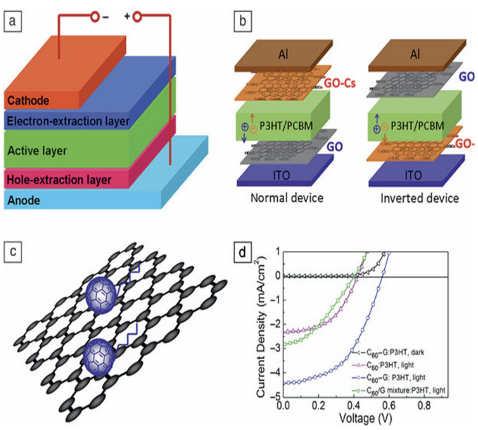


**Fig.2 Device structure of a polymer solar cell (PSC) in the normal configuration.**

In spite of their consistently low power conversion efficiencies (PCEs), PSCs possess numerous advantages in terms of affordability and adaptability. Substantial research has been conducted on carbon nanoparticles and their potential applications in solar solar cells. The transparent electrode that is employed most frequently in solid-state capacitors (PSCs) is indium tin oxide (ITO). Its manufacturing costs are exceptionally high, and it is susceptible to brittleness. An additional obstacle to the implementation of ITO electrodes is the limited availability of indium in nature. Broad, continuous, single- or few-layer graphene sheets are produced through chemical vapour deposition (CVD), which offers a cost-effective and viabl

### 3.3 Material field - Radiator

The graphene nanoplatelets (GnP) had a diameter (d) of 15mm and a thickness (t) that varied from 5 to 10 nm. The GnP were procured from a commercial supplier (XG Sciences, USA).In order to graphically represent GnP, scanning electron microscopy and transmission electron microscopy are implemented. The covalent or non-covalent functionalization approach is frequently employed to generate stable carbon-based nanofluid dispersions. Powerful acids are frequently employed in the covalent functionalization approach to introduce structural defects into the planar structure of GnP. The increased phonon scattering will result in a decrease in the inherent thermal conductivity of GnP under these conditions. As a result, in the current study, we employed a non-covalent functionalisation strategy to generate stable dispersions. In the present investigation, a surfactant with the molecular formula $C_{24}H_{39}NaO_4$ was employed at a concentration of 0.75 vol%, sodium deoxycholate (SDC).

The base fluid consisted of a 70% de-ionized water and 30% ethylene glycol solution. The fluid with a concentration of 0.75 vol% of SDC will be referred to as the 0 vol% fluid. The H2O-EG combination was subjected to intensive ultrasonic vibration for 2 hours using the Probe Sonicator (QSonica, USA, Power Rating: 700W, Frequency: 20kHz) in order to directly incorporate graphene nanoplatelets.A fluid was subsequently prepared with varying volume concentrations of GnP, including 0.001%, 0.01%, 0.1%, 0.2%, 0.3%, 0.4%, and 0.5% theogen. In order to assess the potential for particle sedimentation, the nanofluids constituted of (GnP/H2O-EG) were maintained in a quiescent state for a duration exceeding 15 days.. The nanofluid dispersion that had been generated did not exhibit any discernible sediment deposition after 15 days. The anofluid is depicted in Fig. 3(a) and (b) at its maximal concentration (0.5vol%) after 5 minutes and after 15 days.

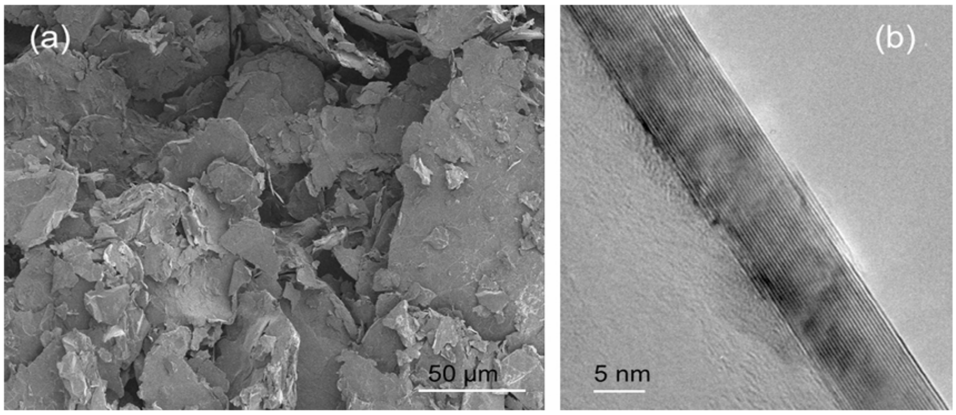


**Fig. 1.** (a) SEM (b) TEM visualization of GnP.

**Fig.3 (a) SEM (b) TEM visualization of GnP**

Additionally, experimental analysis was implemented to evaluate the stability of the nanofluids that were generated. This was achieved by employing a zetapotential analyser from Horiba NanoparticaSZ-100 in the United States and an absorption spectrometer from PG Instruments in the United Kingdom. Section 2.2: Evaluation of thermophysical properties the heat transfer coefficient is significantly influenced by the thermo-physical properties of coolants in thermal systems. The thermal conductivity (knf), viscosity (mnf), density (qnf), and specific heat capacity (Cpnf) of GnP/H2O-EGThe hotwire transient method, capillary viscometer, electronic weight-in-balance, and differential scanning calorimeter are employed to ascertain nanofluids within the temperature range of 30 to 50 C. Initially, the thermo-physical characteristics of a purified base fluid (H2O-EG=70:30) were analysed to confirm the precision of the measurement methodologies. This was done in comparison to pre-existing data sources from ASHRAE.A fluctuation of less than ±2.5% was observed [8].

### 3.4 Bio-medical field – onco therapy

Not too long ago, a study was carried out to investigate the possibility of enhancing the efficacy of therapeutic treatments by employing multi-combination therapy that makes use of graphene-based nanomaterials (GBNMs). For the purpose of carrying out a number of different combination treatments, Wo et al. produced nanocomposites that were covered with liposomes. The construction of these nanocomposites was aided by HMNS/SiO2/GQDs-Dox. Photothermal therapy (PTT), photodynamic therapy (PDT), magnetomechanical treatment, and chemotherapy were some of the treatments that were included in this collection of treatments [9]. During the course of the experiment, the nanocomposites demonstrated strong anti-tumor characteristics after being subjected to laser irradiation and a magnetic field each by itself. These graphene-based nanomaterials (GBNMs), which have demonstrated a high level of therapeutic efficacy, have the potential to be utilized in photothermal ablation (PTA) and photodynamic treatment (PDT). Another advantage that GBNMs has is that they possess exceptional electrical properties, which make it possible for them to be utilized for detection purposes. It was Lee et al. who first presented a contemporary endoscopic instrument that has diagnostic and therapeutic capabilities. This device was an integral part of their presentation. Through the utilization of graphene composites that are applied inside a framework of transparent bioelectronics, the purpose of this work is to enhance the process of tumor diagnostics. As a result of their remarkable transparency, stability, and low contact impedance at the interface between tumors and endoscopes, graphene hybrid materials are becoming an increasingly significant component in the field of diagnostics. On the other hand, graphene hybrid materials are an essential component of the sector. An evaluation of their diagnostic capability was made possible by the examination of both healthy tissue and HT-29 tissue that was obtained from transparent bioelectronics that had been combined with graphene. In order to evaluate its performance via the detection process, specifically with regard to quality, this examination was carried out [10].

## 4. Challenges and prospects

Although graphene has promising futures, there are still barriers in the way of their general use. There are a huge number of challenges in producing large-scale, uniformly-quality graphene sheets and incorporating them into current production methods that call for more study and advancement. For deployment to be effective, it is also

ISSN 2959-6157

essential to overcome problems with heat dissipation and compatibility with current electronic components.

Before graphene-based products can be sold commercially, a number of issues and concerns need to be resolved. For instance, purely obtaining graphene is extremely expensive and challenging. Because impurities are easily obtained, it is vital to reduce contamination while handling and processing graphene as it may seriously impair its performance and dependability in a variety of applications. For example, defects and scattering centers brought about by impurities can impede the flow of electrons, resulting in lower conductivity and worse performance in electrical devices.

In addition, the lack of band gap would also be a huge problem for graphene. In optoelectronics, graphene does not have the ability to absorb or emit light at specific wavelengths which is needed in some devices. For the transistors, high leakage currents result from graphene-based transistors' inability to completely switch off in the absence of a band gap [11].

Graphene is being expected to open a door for a smaller and more powerful devices, leading them working much quicker, also making them flexible. Therefore, it is required that finding new production methods to manufacture graphene much cheaper and quicker. Scientists are projecting graphene having a lot of prospects that it has huge variety of potentials in different fields. Graphene has been discovered to be a great option to be used in those devices because of its intrinsic transparency because of its transparency.

Graphene is considered the most flexible material due to its properties, and graphene-based composites can also benefit from this. Recently, almost all the commercial batteries and capacitors cannot compare with those containing graphene, because graphene could improve them. Those batteries and capacitors applied in the electrochemical electric storage industries could be bendable and not rigid anymore if using graphene-based composites.

In transportation industry nowadays, there are almost 33% of energy is consuming in the world. While this is considered the main cause of the extreme pollution and greenhouse gas emissions in urban cities. A material with great potential for use in car frames is graphene-integrated composites, it is very light, therefore it can make the car frames much lighter. These graphene-based composites always consist of carbon fibers, and they are usually thick for about a few millionths of a meter. Graphene has remarkable aspect ratio, and mechanical strength which lead it to be able to emphasize and improve the weak points if added to the composites, especially at the cross between different components [12].

## 5. Conclusion

In conclusion, the discovery of graphene, which some refer to as the "miracle material of the future," is more than simply a common material. It has the potential to drastically change and improve many aspects of our life. Its amazing qualities, such as super strength, transmission of heat and electricity, transparency, and flexibility make it considered the perfect material for a variety of applications in the fields of electronics, energy, materials and biomedicine, as mentioned before, which are all being extensively studied and explored. It is a promising material in the electronics industry, with potential applications in displays, high-voltage distribution lines, and adaptable devices. Carbon nanoparticles and graphene sheets are being researched for solar solar cell applications. The transparency, stability, and low contact impedance also make graphene-based nanomaterials valuable in diagnostics.

However, to have this promise, there are still obstacles must be resolved, for instance, the problem with mass production and try to have a cost reduction. As these obstacles existing, graphene still has huge potentials in the future technology development. It is a material that scientists are significantly interested in which makes it having a bright future ahead of it. Research on the material is continuing and promises to have various new discoveries. The impact of graphene will soon accelerate as new characterization methodologies, production techniques, and, of course, functionalization approaches becoming apparent. The world of graphene is essentially at our fingertips, ranging from everyday materials and medical applications to semiconductors and advanced battery technology. Graphene is a remarkable invention in the modern world of science and engineering, for example. The path ahead may full of challenges and barriers, but the potential rewards are possibly offending the whole of society in the future.

## 6. Authors Contribution

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

## 7. References

[1] Geng H, Peng Y, Qu L, et al. Structure design and composition engineering of carbon-based nanomaterials for lithium energy storage. Advanced Energy Materials, 2020, 10(10): 1903030.

[2] Raia R, Kumarb S. A Comprehensive Review on Graphene: Historical Development, Properties, Applications, Challenges and Future Scope. Journal of Management, 2024, 1(4): 150-166.

[3] Zhen Z, Zhu H. Structure and properties of graphene. Graphene. Academic Press, 2018: 1-12.
[4] Avouris P, Xia F. Graphene applications in electronics and photonics. Mrs Bulletin, 2012, 37(12): 1225-1234.
[5] Green M A, Emery K, King D L, et al. Solar cell efficiency tables (version 22). Progress in photovoltaics, 2003, 11(5): 347-352.
[6] García I, Rey-Stolle I, Hinojosa M, et al. Space III-V multijunction solar cells on Ge/Si virtual substrates. 2019 European Space Power Conference (ESPC). IEEE, 2019: 1-6.
[7] Steim R, Kogler F R, Brabec C J. Interface materials for organic solar cells. Journal of Materials Chemistry, 2010, 20(13): 2499-2512.
[8] Handbook A F. American society of heating, refrigerating and air-conditioning engineers. Inc.: Atlanta, GA, USA, 2009.
[9] Wang Y, Li J, Li X, et al. Graphene-based nanomaterials for cancer therapy and anti-infections. Bioactive materials, 2022, 14: 335-349.
[10] Shafiee A, Iravani S, Varma R S. Graphene and graphene oxide with anticancer applications: Challenges and future perspectives. MedComm, 2022, 3(1): e118.
[11] Chen S. Fabrication method may enable epitaxial graphene for electronics. Springer, 2024.
[12] Han T H, Kim H, Kwon S J, et al. Graphene-based flexible electronic devices. Materials Science and Engineering: R: Reports, 2017, 118: 1-43.