THE IMPORTANCE OF STUDYING GRAPHENE-BASED NANOMATERIALS.

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Annotatsiya: Grafen asosidagi nanomateriallar (GBN), jumladan, grafen oksidi (GO), grafen va qaytarilgan grafen oksidi (rGO), o‘ziga xos tuzilishi va fizik-kimyoviy xossalari tufayli ilmiy tadqiqotlarda dolzarb yo‘nalishlardan biri hisoblanadi. Ayniqsa, biotibbiyot sohasida GBN keng qo‘llanib, to‘qimalar muhandisligi, biovizualizatsiya, o‘simtalarga qarshi dorilarning maqsadli yetkazib berilishi, biosensorlarning ishlab chiqilishi, antibakterial va virusga qarshi materiallar yaratish kabi yo‘nalishlarda samarali natijalarga erishilmoqda. Ushbu maqolada GBN ning biotibbiyotdagi ilovalari, mexanizmlari va istiqbollari batafsil tahlil qilinadi.

Kalit so‘zlar: GBN, biosensorlar, quyosh panellari, nanomateriallar, dispersiya, biotibbiyot, fermentlar, biomolekulalar, termosuyuqliklar, biovizualizatsiya.

Аннотация: Наноматериалы на основе графена (GBN), включая оксид графена (GO), графен и восстановленный оксид графена (rGO), благодаря своей уникальной структуре и физико-химическим свойствам, являются одним из актуальных направлений научных исследований. Особенно широкое применение GBN находят в биомедицине — в инженерии тканей, биовизуализации, целевой доставке противоопухолевых препаратов, разработке биосенсоров, создании антибактериальных и противовирусных материалов. В данной статье подробно анализируются применения, механизмы и перспективы использования GBN в биомедицине.

Ключевые слова: GBN, биосенсоры, солнечные панели, наноматериалы, дисперсия, биомедицина, ферменты, биомолекулы, теплоносители, биовизуализация.

ISSN 3030-3907

Annotation: Graphene-based nanomaterials (GBN), including graphene oxide (GO), graphene, and reduced graphene oxide (rGO), are among the current directions in scientific research due to their unique structure and physicochemical properties. Especially, GBN are widely used in the field of biomedicine, and effective results are being achieved in areas such as tissue engineering, bioimaging, targeted delivery of anticancer drugs, development of biosensors, and creation of antibacterial and antiviral materials. This article provides a detailed analysis of the applications, mechanisms, and prospects of GBN in biomedicine.

Keywords: GBN, biosensors, solar panels, nanomaterials, dispersion, biomedicine, enzymes, biomolecules, thermofluids, bioimaging.

Introduction

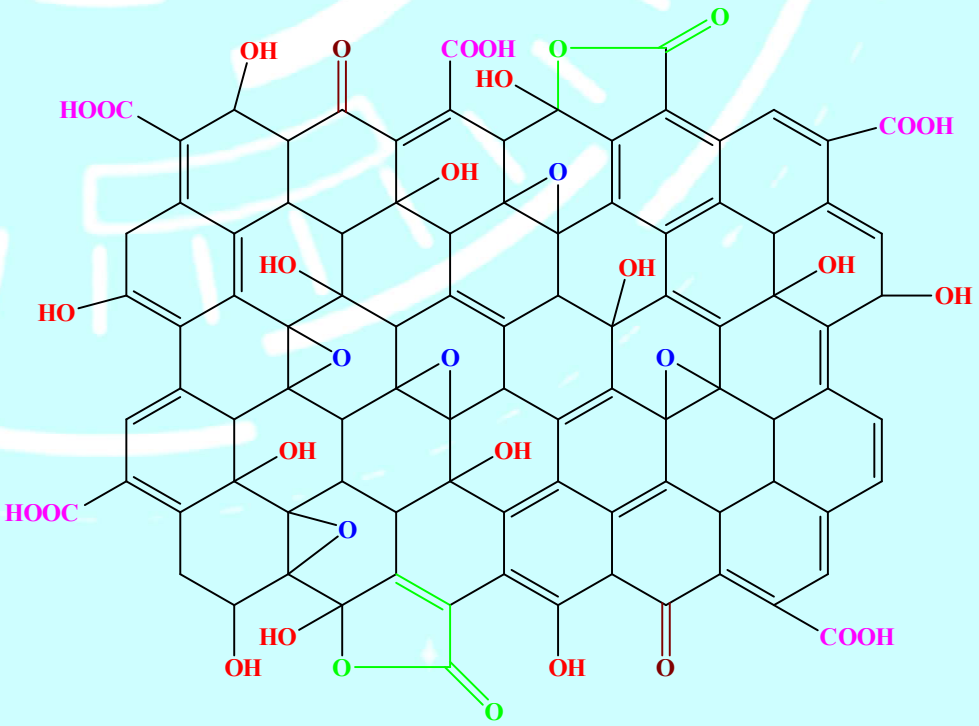
One of the most important application areas of graphene-based nanomaterials (GBN) is biomedicine, where their unique physicochemical and structural properties offer a wide range of possibilities. GBNs are primarily utilized in tissue engineering [1], where they serve as scaffolds that promote cell adhesion, proliferation, and differentiation due to their high surface area and biocompatibility. In bioimaging, graphene derivatives are used as efficient contrast agents because of their strong optical absorption and fluorescence quenching capabilities. Another major area of interest is the targeted delivery of anticancer drugs, where GBNs act as nanocarriers that can be functionalized with specific ligands to recognize and bind to cancer cells, thereby minimizing side effects and improving therapeutic efficacy. Additionally, GBNs play a crucial role in the development of biosensors, enabling highly sensitive and selective detection of biomolecules for diagnostic and monitoring purposes. Moreover, GBNs are actively investigated for the creation of antiviral, antibacterial, and antifungal materials due to their ability to disrupt microbial cell membranes and inhibit pathogen growth. They are also studied for their role in transport processes of biomolecules such as enzymes, proteins, genes, RNA, and DNA, offering great promise for gene therapy, molecular diagnostics, and regenerative medicine. Overall, the integration of GBNs into biomedical applications is paving the way for innovative approaches in modern healthcare and biotechnology.

Furthermore, materials for energy applications can be created based on GBN: (fuel cells), batteries, and solar panels, "smart" materials [2], thermofluids, as well as in the form of materials for water disinfection and desalination. GBN can be covalently and non-covalently functionalized. The functionalization of GBNs leads to the improvement of their electrical, optical, thermal, and mechanical propertie. Graphene is a carbonaceous material [3] in which the number of layers can vary [4]. Several approaches exist for the synthesis of graphene: chemical vapor deposition (CVD), electrochemical exfoliation of graphite, the mechanochemical

ISSN 3030-3907

method [5], as well as through the chemical and thermal reduction of GO, which leads to the formation of rGO.

Graphene consists of sp^2-hybridized carbon atoms forming two-dimensional nanomaterials, while GO contains various oxygen-containing functional groups distributed across its surface, such as carboxyl, carbonyl, and lactol groups at the edges of the GO layers, in addition to epoxy and hydroxyl groups. rGO is a form of GO where the majority of the oxygen-containing functional groups have been reduced by substances such as hydrazine hydrate or biomolecules (e.g., amino acids). A graphene monolayer was first obtained in 2004 by Andre Geim and Konstantin Novoselov [6]. GO was first synthesized in 1859 by Benjamin Brodie through the oxidation of graphite using a mixture of oxidizing agents potassium chlorate and concentrated nitric acid [7]. However, the most efficient method was developed in 1957 by William Hummers and Richard Offeman using a mixture of oxidizing agents consisting of sulfuric acid, sodium nitrate, and potassium permanganate [8].



The structure of GO.

Due to the abundance of functional groups on the GO surface, as well as the presence of carbon atoms in the sp^2 hybridization state, a wide range of organic reactions can be utilized for the further functionalization of GBN: amidation, esterification, 1,3-dipolar cycloaddition, halogenation, and others. Additionally, the functionalization of GBN can also be achieved through the formation of hydrogen bonds, π-π interactions, and hydrophobic interactions. The reactions mentioned above enable the creation of unique materials for biomedical purposes, such as the development of drugs for the treatment of oncological diseases [9], drug

ISSN 3030-3907

and biomolecule delivery systems, biosensor development, antiviral materials [10], as well as materials with antibacterial and antifungal properties. Among graphene-based nanomaterials, GO holds the greatest potential for use in nanomedicine due to the following reasons:

I. GO contains various functional groups that allow for further surface functionalization;

II. The functionalization of GO enhances its biocompatibility;

III. The presence of oxygen-containing functional groups ensures the stability of aqueous GO dispersions.

Conclusion: The wide possibilities of graphene-based nanomaterials (GBN) in the field of biomedicine are having a significant impact on the development of modern medicine and pharmaceuticals. These materials play a crucial role in tissue engineering, biovisualization, targeted drug delivery for anticancer treatments, biosensor development, and the creation of effective materials against various microorganisms. Due to their large surface area, biocompatibility, and ease of functionalization, GBNs provide new opportunities for improving diagnostic accuracy and therapeutic effectiveness. Additionally, innovative solutions in biomedicine are being proposed through technologies for the transport of biomolecules such as enzymes, proteins, genes, RNA, and DNA, which open up new perspectives for gene therapy and molecular diagnostics. In the future, the use of GBN materials will contribute to the development of more efficient, safe, and personalized technologies in this field.

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ISSN 3030-3907