DOI 10.54596/2309-6977-2022-2-147-151
УДК 620. 3
МРНТИ 55.09.43

# MODERN MATERIALS IN MECHANICAL ENGINEERING

**Shakirova M.A., Ratushnaya T.Yu., Bikbaev R.D, Drobyshev A.V.**
(e-mail: dina_191728@mail.ru, tratushnaia@mail.ru, romanbik18112000@gmail.com, alexdrobing@gmail.com)
*M. Kozybayev North Kazakhstan university, Petropavlovsk, Kazakhstan,*

**Annotation**

This article describes the concept of graphene and metamaterial, their possible structure, principle of operation, properties, basic technologies, as well as the possibility of using these materials in industry. The relevance of modern materials in the future is revealed and the main events in the history of the development of this type of materials are indicated.

**Keywords**: Graphene, two-dimensional material, nanomaterial, properties, metamaterials, superlenses, metasurfaces, acoustic waves.

# СОВРЕМЕННЫЕ МАТЕРИАЛЫ В МАШИНОСТРОЕНИИ

**Шакирова М.А., Ратушная Т.Ю., Бикбаев Р.Д., Дробышев А.В.**
(e-mail: dina_191728@mail.ru, tratushnaia@mail.ru, romanbik18112000@gmail.com, alexdrobing@gmail.com)
*Северо-Казахстанский университет им. М. Козыбаева, Петропавловск, Казахстан*

**Аннотация**

В данной статье описывается понятие графена и метаматериала, их возможное строение, принцип работы, свойства, основные технологии, а также возможности использования этих материалов в промышленности. Раскрывается актуальность современных материалов в будущем и указаны основные события в истории развития данного типа материалов.

**Ключевые слова**: Графен, двухмерный материал, наноматериал, свойства, метаматериалы, суперлинзы, метаповерхности, акустические волны.

# МАШИНА ЖАСАУДАҒЫ ЗАМАНАУИ МАТЕРИАЛДАР

**Шакирова М.А., Ратушная Т.Ю., Бикбаев Р.Д., Дробышев А.В.**
(e-mail: dina_191728@mail.ru, tratushnaia@mail.ru, romanbik18112000@gmail.com, alexdrobing@gmail.com)
*М. Қозыбаев атындағы Солтүстік Қазақстан университеті, Петропавл, Қазақстан*

**Аңдатпа**

Бұл мақалада графен және метаматериал түсінігі, олардың мүмкін құрылымы, жұмыс істеу принципі, қасиеттері, негізгі технологиялары, сондай-ақ осы материалдарды өнеркәсіпте пайдалану мүмкіндіктері сипатталған. Болашақта заманауи материалдардың өзектілігі ашылып, осы түрдегі материалдардың даму тарихындағы негізгі оқиғалар көрсетілген.

**Түйін сөздер**: Графен, екі өлшемді материал, наноматериал, қасиеттер, метаматериалдар, суперлинзалар, метабеттер, акустикалық толқындар.

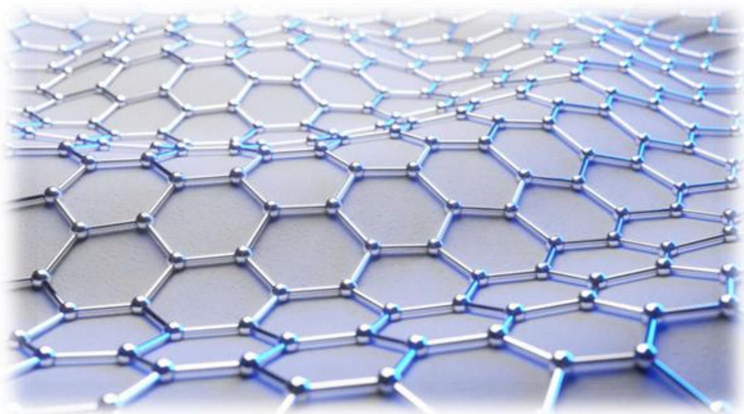
**Introduction**

The beginning of the 21st century was a revolutionary start in the development of nanotechnologies and the use of nanomaterials in various fields of human activity. An important feature of nanotechnology is that a person creates materials with new physical-chemical, physical-mechanical and biological properties.

New materials are constantly emerging and becoming more and more perfect. The fantastic properties of new materials are more interesting to study than the materials themselves, since these properties sometimes violate the laws of physics. Graphene and metamaterials are currently one of such composite materials.

These materials predetermine the development of many innovative areas of scientific and industrial activity. The technique of using graphene and metamaterial is the basis of the industry of the future: plasmonics, photonics, spintronics, bioinformatics.

Graphene is the thinnest in the world, as its thickness is one atom! And this proves that in fact graphene is a two-dimensional material, but still we can hold it in our hands, and this never ceases to amaze. The most curious thing is that graphene will never be in short supply, because it has the same carbon composition as the graphite pencil lead with which we write. Scientists have calculated that the content of graphene in one millimeter of graphite is equal to about three million of its layers (Picture 1).



Picture 1. Structure of graphene

This excellent material was discovered in 2004 by Konstantin Novoselov and Andrey Geim at the University of Manchester when they were studying the conductivity of graphite. [1]. Scientists discover graphene thanks to ordinary duct tape. They glued adhesive tape to a piece of graphite and thus managed to get a single layer of material, so graphene was born. And in 2010, they were awarded the Nobel Prize in Physics for this invention.

Graphene is an incredible stretchable material, it can stretch up to 25% of its length and is also the hardest known material. It is even harder than diamonds, which says a lot: to destroy graphene, you need to apply pressure equal to that exerted by an elephant balancing on the tip of a pencil.

Despite being two-dimensional, graphene can still be seen without even needing a microscope. A single layer of atoms can be seen with the naked eye. And another unique feature of graphene is its electrical conductivity. This material conducts electricity faster and more efficiently than any other known material. The current density of graphene is millions of times greater than the current density of copper [2]. Its internal mobility is better than silicone. Thus, the electrons do not encounter resistance when they pass through graphene, as a result, the material can be used to produce batteries, whose holding capacity will be ten times higher than current models.

Another remarkable property of graphene is its ability to expand when cooled and contract when heated. There are no other materials with similar properties. Not a single helium atom can penetrate through graphene, which makes graphene the most impenetrable material in the world, therefore, it can work as a gas detector. And while atoms can't get through graphene, electrons won't have that problem. According to Andrei Geim, this makes graphene an indispensable material for experiments in the field of quantum physics.

How can graphene be used? Graphene can solve the problem of water shortage in many countries, if you make a special graphene filter, it will pass water through itself, while filtering out salt and other harmful impurities [3]. This will be a revolution in the field of desalination. In 2018, scientists at an Australian research organization made seawater drinkable after passing water through a graphene filter just once. Dong Hang Seo, a scientist on the research team, claims that this technology can make even the dirtiest water drinkable.

Even one layer of graphene is very strong. Two layers of graphene is what you need for body armor. Georgia Institute of Technology researchers recently demonstrated how two layers of graphene can remain intact even after being pierced with a diamond tip.

Scientists at the University of Illinois say graphene can help detect cancer cells in the body, and researchers at the University of Texas have invented temporary tattoos based on the material. These tattoos track a person's health, including body water levels and body temperature.

New graphene-based batteries can be recharged incredibly quickly. Charging from 0 to 100% is about 15 minutes, and it will be possible to charge them up to 3500 times.

When manufacturers start using graphene to make smartphones, their screens will soon be able to bend in any direction, because one of the main properties of graphene is its plasticity - for this reason, all electronics will have this property.

In Switzerland, graphene-based motor oil is actively used.

It differs from ordinary oil in that during operation, one layer of graphene slides over another layer of graphene and thereby reduces the friction force. Another plus of this engine oil is that graphene reduces its consumption by 10%, does not require replacement and provides excellent lubrication of parts for 3 years. If we consider the transmission oil, then this oil reduces the operating temperature by up to 80%, reduces the level of noise and vibration.

Nobel laureate Andrei Game, together with his assistants, were able to find out that inside graphene it is possible to create conditions identical to those in which matter arises from vacuum, namely in the vicinity of black holes and other space objects [4].

Thus, this nanomaterial will be in great demand and interest in the modern and dynamically changing world.

Metamaterials are special composite materials that are obtained by an unnatural modification of particles embedded in them. The change in the structure occurs at the nanolevel, which makes it possible to change the size, shape and periods of the atomic lattice.

Due to the artificial transformation of the structure, the modified object acquires completely new properties that are absent from natural materials [5].

The main properties of metamaterials is interaction with electromagnetic and acoustic waves. Since metamaterials are composite materials synthesized by man, a person can create various structures from a metamaterial, which are affected by waves in an unusual way.

By design, metamaterials are matter, the features of which are determined by the microscopic structure. They are synthesized by introducing into a certain natural element periodically repeating structures with arbitrary geometric shapes that affect the magnetic and dielectric susceptibility of the original structure.

For clarity, these structures can be represented as artificial atoms, which are larger in comparison with real ones, which makes it possible to work with them. Synthesizing the structure, the researcher can create a structure of arbitrary geometry with different parameters that have special properties.

The key feature of the synthesized materials is the periodicity of their structure. The periodic structure can be one-dimensional, two-dimensional and three-dimensional, that is, it can have any structure. Two-dimensional metamaterials can be used as coatings applied to some substrate or other surface and are called meta-surfaces. Meta-surfaces give certain properties to surfaces that natural materials do not have [5].

The creation of metamaterials became possible only due to the fact that electromagnetic waves with a large length can interact with sufficiently large segments in the same way as with atoms, perceiving them as one integral material. Thus, particles of a metamaterial can be considered as atoms that create new structures.

One of the main directions in the development of metamaterials is the ability to change the behavior of visible spectrum waves, create media with a negative refractive index, and bend around the material in waves. But the interaction of metamaterials with acoustic and electromagnetic waves is also being studied [6].

Currently, the most promising technologies based on the properties of metamaterials are:

- Creation of a "superlens" that can exceed the diffraction limit of conventional optics, making it possible to study particles that cannot be seen with a conventional microscope.
- Various meta-surfaces that can increase the efficiency of electricity generation by photovoltaic converters, which is a leap in the development of alternative energy and in the future can replace completely fuel-powered power plants.
- The ability of certain waves to flow around the spectrum of metamaterials makes it possible to achieve relative or even absolute invisibility. So far, scientists David Smith, David Schurig of Duke University and John Pendry of Imperial College London have managed to create something similar for microwaves invisible to the human eye, but a similar metamaterial can also be created for the visible wavelengths of the spectrum.
- The use of metamaterials in printed antennas results in better performance at a smaller size.
- Ability to manipulate acoustic waves as well as light. It has already been possible to focus sound with the help of metamaterials and to force a small ball to stay in its stream with a beam of focused sound waves.
- Devices working with micro particles. Optical tweezers are already used in modern laboratories to capture particles of micron or submicron size [7].

The very first work in this direction was carried out at the end of the 19th century. The Bengal scientist Jagadis Chandra Bose conducted a microwave experiment in 1898 to study the polarization properties of the structures he created with a curved configuration. In 1914, Lindman acted on artificial environments, consisting of a large number of randomly arranged wires, coiled into a spiral and nested in an environment that fixed them. In 1946–1948 Winston E. Kok was the first to create a microwave lens from conducting spheres, disks and periodically arranged strips of metal, they form an artificial medium with a specific effective refractive index. The history of materials with a negative refractive index was first mentioned in the work of the Soviet physicist Viktor Veselago, in the journal Uspekhi fizicheskikh nauk in 1967. The article talked about the possibility of the existence of a material with a negative refractive index, which was called "left-handed". The author came to the conclusion that when interacting with this material, many known optical effects of wave propagation differ significantly.

Studies of the metamaterials properties, artificial structures with unique electromagnetic properties, allow scientists from all over the world to make new significant discoveries in the field of optical signal control. The transfer of information using photons, the integration of electronics and optical devices will reduce the size of computers and increase their speed.

## Conclusion

Nevertheless, the physics of graphene and metamaterials is very interesting, not only because of its exciting potential applications, but also in itself, as an example of an as yet unrealized opportunity to discover amazing phenomena in a field of science (classical macroscopic electrodynamics), where, it would seem, everything has been researched and systematized for a long time

**References:**

1. Aleksenko A.G. Graphene. - M.: "Laboratory of Knowledge", 2019. - 175 p.
2. Gubin S.P., Tkachev S.V. Graphene and related carbon nanoforms. - M.: "Librocom", 2011. - 152 p.
3. Graphene. Device and application. Features and prospects// Electronic publication – https://electrosam.ru/glavnaja/jelektrotehnika/raschjoty/grafen/
4. Emergence of matter from vacuum was reproduced inside graphene//Electronic publication – https://nauka.tass.ru/nauka/13548769
5. I.B. Vendik, O.G. Vendik Metamaterials and their application in microwave technology. Journal of Technical Physics, Volume 83, no. 1, 2013.
6. Veselago V.G. Electrodynamics of substances with simultaneously negative values of ε and μ // Uspekhi fizicheskikh nauk. - M.: Nauka. The main edition of physical and mathematical literature, 1967. - July (vol. 92). - S. 517-526.
7. Metamaterials. Types and device. Work and application. // Electrosam.Ru: [Electronic resource] - https://electrosam.ru/glavnaja/jelektrotehnika/metamaterialy.