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Graphene breakthrough into future technology: the 2010 Nobel Prize in Physics Laureate Sir Konstantin Sergeevich Novoselov

Vyacheslav M. Tyutyunnik ✉

Tambov State Technical University, 106, Sovetskaya St., Tambov 392000, Russian Federation,
International Nobel Information Centre (INIC), 30-6, Pervomaiskaya Sq., Tambov 392002, Russian Federation

✉ vmtyutyunnik@gmail.com

Abstract: The paper explores the research work of one of the youngest winners of the 2010 Nobel Prize in Physics, Konstantin Sergeevich Novoselov (born 23.08.1974). Since 2004 when the single-atom graphene was extracted and the research findings were published for the first time, the graphene breakthrough has been made. The paper focuses on the main milestones of Novoselov's biography and analyzes his publishing activity between 2004 and 2018. The data confirming the highest number of citation of Novoselov's publications in the world's leading scientific journals are presented. Novoselov's main scientific awards are listed.

Keywords: 2010 Nobel Prize in Physics; Konstantin Sergeevich Novoselov; grapheme; publishing activity; citation; technologies of the future.

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Графеновый прорыв к технологии будущего: лауреат Нобелевской премии по физике 2010 года Сэр Константин Сергеевич Новосёлов

В. М. Тютюнник✉

Тамбовский государственный технический университет,
ул. Советская, 106, Тамбов 392000, Российская Федерация,
Международный Информационный Нобелевский Центр (МИНЦ),
Первомайская площадь, 30-6, Тамбов 392002, Российская Федерация

✉ vmtyutyunnik@gmail.com

Аннотация: Рассмотрена деятельность одного из самых молодых лауреатов Нобелевской премии по физике 2010 г. Константина Сергеевича Новосёлова (род. 23.08.1974). Показано, что после получения одноатомной плёнки графена и первой публикации 2004 г., в мире начался графеновый прорыв к технологии будущего. Описаны основные вехи биографии Новосёлова, проанализирована его публикационная активность в период 2004 – 2018 гг., приведены данные, свидетельствующие о самом высоком уровне цитируемости публикаций Новосёлова в ведущих научных журналах мира. Перечислены основные научные награды, увлечения Новосёлова.

Ключевые слова: Нобелевская премия по физике 2010 года; Константин Сергеевич Новосёлов; графен; публикационная активность; цитируемость; технологии будущего.

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Carbon in the form of two three-dimensional allotropic modifications – graphite and diamond – has been used in everyday life, in science and technology since ancient times. At the end of the 20th century, one-dimensional nanotubes and zero-dimensional fullerenes were added to them. This resulted in the rapid development of scientific research and technologies based on them [1–5]. However, it was still impossible to produce only a two-dimensional modification of carbon – graphene. Meanwhile, the research into mesoscopic physics (mesoscopy), as one of the most interesting branches of condensed matter physics, and nanotechnology showed convincingly that such a modification was possible.

Graphene consists of ultrathin layers (one atom thick) of carbon atoms linked into a hexagonal structure (consisting of hexagons with common sides). It is the thinnest and, at the same time, the most durable material with excellent conductive properties. In terms of thermal conductivity, it surpasses all materials known to date. Two-dimensional graphene layers are almost transparent, but extremely dense and impenetrable even for monoatomic helium molecules.

The theoretical study of graphene began long before the production of real samples of the material, since graphene is the basis for constructing a three-dimensional crystal of ordinary graphite. However, it was not possible to extract graphene experimentally for a long time. The discovery of carbon nanotubes revived an interest in it. Attempts to produce graphene attached to another material began with experiments using a simple pencil lead, and continued using an atomic force microscope for mechanical removing layers of graphite. Previously it had been shown theoretically that a free ideal two-dimensional film cannot be produced due to instability caused by folding or twisting). It was made possible only in 2004, when K.S. Novoselov and A.K. Geim (in collaboration with six other researchers) published an epoch-making article in the *Science* journal [6], where they reported on the production of graphene on an oxidized silicon substrate using the micromechanical lamination technology. Later, exfoliation and graphite intercalation were used most successfully. The initial reports of Novoselov and Geim about the separation of one atomic layer from the graphite crystal were not taken seriously, and the journals refused to publish their findigs. It was only in October 2004, when a real graphene boom began – a breakthrough to the technology of the future. Six years had passed before the 2010 Nobel Prize in Physics was awarded to two MIPT graduates, Novoselov and Geim, "for fundamental experiments with two-dimensional material graphene" (Fig. 1) [7, 8].

In the Nobel lecture, Novoselov compared two-dimensional graphene with E.E. Abbott's "Flatland" and gave a detailed analysis of the properties and applications of this unusual crystal [9].

Konstantin Sergeevich Novoselov was born on August 23, 1974 in Nizhny Tagil in a typical Soviet family. His parents were well-educated; his father, Sergei Viktorovich, was an engineer at the Uralvagonzavod, and his mother, Tatyana Glebovna, was an English teacher. His passion for physics began as early as in the sixth grade of secondary school. In 1986, he took first place in the regional Olympiad in physics, and at the All-Union Olympiad for schoolchildren of the USSR he was in the top ten. After graduating with honors from Moscow Institute of Physics and Technology (specialising in nanoelectronics) in 1997, he worked at the Institute for Problems of Microelectronics Technology of the Russian Academy of Sciences (Chernogolovka) for two years, combining it with postgraduate study. However, he was awarded PhD degree at the University of Nijmegen at the end of 2004. He moved to the Netherlands in 1999, and completed his research work under supervision of Prof. Andre Geim. Since 2001 he has been affiliated with the University of Manchester (UK), where he continues his research as a professor, and combines it with work at National University of Singapore.

Novoselov is married (Fig. 2). In 2009, he and his wife had two twin daughters – Sofia and Victoria, whom they took to Stockholm to the Nobel Prize Award Ceremony. On December 31, 2011, he was awarded the knighthood and given the title of Sir.

Fig. 1. Novoselov's Nobel diploma. Copyright ©The Nobel Foundation 2010

Fig. 2. Novoselov with his wife Irina Barbolina during the reception at the Royal Swedish Academy of Sciences, 7 December, 2010.
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In 2014, Novoselov was included in the list of the most cited researchers. His publication activity is extremely high [11]. In the WoS database, at the beginning of 2019, 312 of his publications were recorded, of which 289 have been cited since 2004; the total number of citations is 172.525; h-index is 112; 25 publications have been cited more than 1000 times, with 4 out of them being cited more than 10000 times; the average number of citations is 597. The citation diagram by years is as follows (Fig. 3).

In the leading scientific journals of the world, Novosyolov's citation is currently unattainable. For example, in the *Science* journal, the article [6] has been cited 34,000 times, exceeding the citation of the second-place article by three times. Similar pictures are observed in the *Nature* journal and others. In the year when he was awarded the Nobel Prize he owned only 95 publications.

After the Nobel Prize Award Ceremony, Novoselov gave an interview, in which he commented on his possibility of returning to Russia and doing research there. He admitted that he was happy with his work at the University of Manchester, but if he was made an interesting job offer in Russia, perhaps he would return, although it was quite unlikely. The organization of research work in Britain is much simpler and more transparent than in Russia or in Germany. It was not just about money. However, over time, the situation has changed.

In February 2021, it became known that Novoselov is going head the Laboratory of Physics of Programmable Functional Materials at the Russian Center for the Study of the Brain and Consciousness of Moscow Institute of Physics and Technology, which is being created with a private five-year grant of 500 million rubles allocated by V.O. Potanin.

The laboratory will be engaged in interdisciplinary research at the intersection of physics, mathematics, biology, new materials, in particular, the development of ion transistor technologies. Such technologies reveal new methods of studying the brain, sensors for neurophysiological research, computer interfaces.

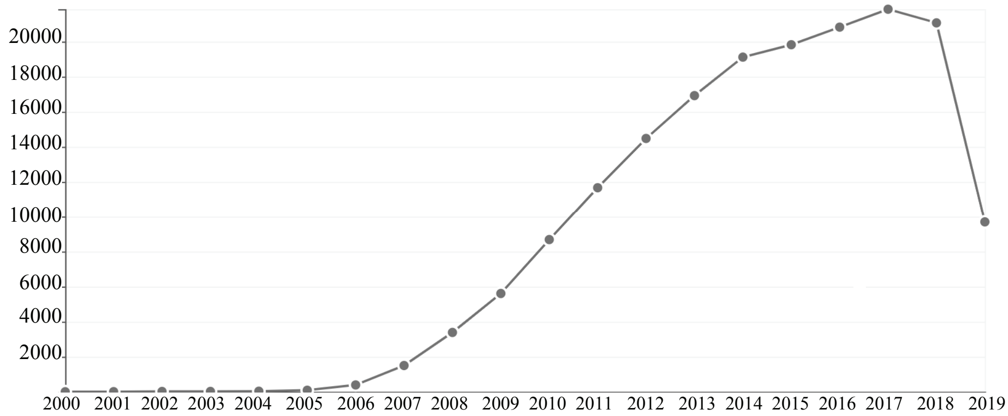

Fig. 3. The curve of Novoselov's publication activity. The ordinate is the number of citations, the abscissa is the years. The dot for 2019 takes into account citations of the first two months

Novoselov has a significant number of scientific awards. He is a member of the Royal Society of London and the US National Academy of Sciences; he has been awarded the Lars Onsager and John Dalton medals, the Otto Warburg and Europhysicist prizes. As a British-Russian citizen, Novoselov has not been included in the group of four Russian Nobel laureates who have not been elected to the Russian Academy of Sciences [12].

Novoselov is not just an outstanding researcher, but also a talented designer and artist. He led the construction project at the Manchester National Graphene Institute and is well known for his work in Chinese calligraphy and Chinese-style drawings.

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Информация об авторах / Information about the authors

Тютюнник Вячеслав Михайлович, доктор технических наук, профессор, Тамбовский государственный технический университет; генеральный директор, Международный Информационный Нобелевский Центр, Тамбов, Российская Федерация; ORCID 0000-0002-2099-5730; e-mail: vmtyutyunnik@gmail.com

Vyacheslav M. Tyutyunnik, D. Sc. (Engineering), Professor, Tambov State Technical University; Director General, International Nobel Information Centre, Tambov, Russian Federation; ORCID 0000-0002-2099-5730; e-mail: vmtyutyunnik@gmail.com

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