165 years since the birth of Academician N. S. Kurnakov
75 years since the birth of I. N. Beloglazov,
professor at the Saint Petersburg Mining University

Metallurgists K. F. Beloglazov, I. N. Beloglazov and nanotechnologies[1]

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The article is dedicated to the 165th anniversary of the birth of academician N. S. Kurnakov (1860–1941) and the achievements of his scientific school, including the works of his scholars and followers from the Beloglazovs dynasty. For the first time, the works of Konstantin F. Beloglazov (N. S. Kurnakov's closest assistant) concerning the physical chemistry of surface phenomena and surface properties of minerals and of interest for the creation of nanostructured materials are analyzed.
The scientific fate of K. F. Beloglazov (1887–1951) is compared with the scientific fate of Peter P. Weimarn (1879–1835), another famous scholar of academician Kurnakov. The expediency of such a comparison is dictated by the following. In the scientific literature there are indications that K. F. Beloglazov continued P. P. Weimarn's unique research in the field of highly dispersed (colloidal) substances. They both were direct scholars of N. S. Kurnakov, belonged to almost the same generation. It is shown that the works of P. P. Weimarn on the production of solids of any degree of dispersity, "starting with molecular", and K. F. Beloglazov's research on the adsorption of substances and the mechanism of flotation made a significant contribution to the development of the scientific foundations of nanotechnology in the 21st century.
Ilya N. Beloglazov (1950–2011), grandson of K. F. Beloglazov, in 2008 became the scientific Head of the Center for Nanotechnology at the St. Petersburg Mining Institute (now the University) and the most actively of the Beloglazovs-Thiemes dynasty continued research in the field of highly dispersed materials. His productive scientific and organizational activities in 2004–2011 allowed the Mining University to become a renowned center for the development of new nanostructured metal materials, including superhydrophobic ones. It is established that professor I. N. Beloglazov made a direct creative contribution to the victory of Mining University developments at international exhibitions (20 medals) and the publication of Russia's first scientific monographs on nanotechnology and special issues on nanostructured metals in the Tsvetnye Metally and Non-Ferrous Metals journals.

Key words: Konstantin F. Beloglazov, Iliya N. Beloglazov, nanotechnology, metallurgy, contribution, solid's surface, Saint Petersburg Mining University.
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Introduction

Nicolay Semenovich Kurnakov is an academician, professor, one of the most famous graduates and professors of the Saint Petersburg Mining Institute (SPMI) (**Fig. 1**). He worked at SPMI for almost half a century and even after moving to Moscow to become the head of the department at Moscow State University, he remained a professor at the Mining Institute in Leningrad for a long time [1–3]. Academician Kurnakov is one of the founders of Russian (Soviet) scientific schools in the fields of metallurgy and material science. Russian and foreign scientific publications note his outstanding achievements as a physicochemist, as the creator of the method of physicochemical analysis and as a scientist who made a great contribution to the study of water-salt systems, which have a massive industrial importance [4–6]. The works of academician Kurnakov and his scientific school played an exceptional role in the establishment of domestic production of aluminum, platinum, various alloys as well as in strengthening the defense capability of the country [4, 7, 8]. In support of this thought we can refer to the statement of Nobel laureate Pyotr Kapitsa: "Without Chernov, Kurnakov and their followers our metallurgy, of course,

[1]Based on scientific literature and personal recollections.

Fig. 1. Academician Nicolay Kurnakov (1860–1941) (*Archives of RAS, F. 701, op. 2, D.442, L. 1*)

Fig. 2. Professor Konstantin Beloglazov (1887–1951) (*Photo courtesy of the Department of General and Physical Chemistry of Empress Catherine II Saint Petersburg Mining University*)

Fig. 3. Professor Iliya N. Beloglazov (1950–2011) [17].

would not have known such good steel that is necessary for our guns, which the army is armed with, nor such magnificent armor, which we make now. And without it, construction engineers would be powerless to create first-class battle tanks" [9, p. 69].

Dozens of works are devoted to the study of N. S. Kurnakov's scientific heritage, and they are repeatedly cited by various researchers [2, 7, 10]. Significantly fewer publications are devoted to the analysis of scientific publications and achievements of N.S. Kurnakov's scholars. Among them were very famous scientists, including N. I. Stepanov (1879–1938), corresponding member of the USSR Academy of Sciences; professor P.P. Weimarn (1879-1935), the founder of the science of nanotechnology; professor K.F. Beloglazov (**Fig. 2**), Stalin Prize laureate, and others [11–13].

This article will be focusing on the activities of K. F. Beloglazov, who was a student of N. S. Kurnakov and worked with him as an assistant at the Department of Analytical Chemistry at SPMI, as well as on the activities of I. N. Beloglazov, our contemporary (**Fig. 3**).

Many works have been written about the life and works of the Beloglazovs scientific dynasty [16–18], which is closely related to the equally famous Thiemes dynasty [14, 15]. However, there is no detailed information about the connection of their research, scientific and organizational activities with the development of nanotechnology. At the same time, on the eve of the birth anniversaries of outstanding scientists Konstantin Beloglazov and his grandson Ilya Beloglazov, it would be extremely important and relevant to consider this issue.

Both of the researchers worked as heads of departments in the Mining Institute in Saint Petersburg (Leningrad) until the end of their days. Their fundamental and applied works were related to the study of problems of metallurgy and processing of mineral resources. In the XXI century nanotechnology and nanomaterials have become a priority area of science and technology development. That ensures sustainable development of the mineral resource sector and fuel and energy complex of the country [19–21]. Taking into account the world priority of the Mining Institute (University) in Saint Petersburg in the field of nanotechnology, which is, first of all, ensured by the works of professor Peter Weimarn [12, 22], there is an undoubted interest to assess the contribution of the Beloglazovs dynasty to this promising research direction.

The **aim of this article** is to establish the contribution of K. F. Beloglazov to the study of highly dispersed systems, including nanomaterials, and to analyze the scientific and organizational achievements of I. N. Beloglazov in the field of nanotechnology.

Research results

K. F. Beloglazov and P. P. Weimarn

The study of the activities of professors K. F. Beloglazov and I. N. Beloglazov is based on the analysis of their scientific works and publications about their biography.[2]

The starting point in the study of Konstantin Beloglazov's involvement in the first nanotechnological research in SPMI (and, therefore, in the world [12, 22])

[2]Besides, the first three authors of this article had a great opportunity to work together under I. N. Beloglazov's authority, to study at his department, to communicate with him (2003–2011) and to listen to the memories of Iliya Beloglazov about his famous ancestor Konstantin Beloglazov. Syrkov A. G. worked at the Faculty of Fundamental and Humanitarian Disciplines when Iliya Beloglazov was Dean of the faculty (2006–2010). He has joint publications on nanotechnology with I. N. Beloglazov, including articles in the Tsvetnye Metally journal [23, 24]. Syrkov A. G. was also deputy to I. N. Beloglazov when the latter was the scientific Head of the Mining University in the direction of "Nanotechnology". Kushchenko A. N. and Yachmenova L. A. were students at the Process and Plant Automation Department, which was headed by professor I. N. Beloglazov. To the same department in 2011 Yachmenova L. A. entered the postgraduate programme.

was the information from the book [13]. It was reported there that K. F. Beloglazov continued the research of professor P. P. Weimarn in the field of highly dispersed (colloidal) systems [13, p. 276]. Today we are well aware of the world-priority works of P. P. Weimarn in 1906–1915 [12, 22]. This fact is confirmed by leading Russian experts [12, 23] and perceived by the international scientific community [26].

Even in his diploma thesis (1914), K. F. Beloglazov investigated the microstructure of copper-antimony alloys [16, 18]. He actively researched the physical chemistry of surface phenomena [27], particularly studying the influence of solid-phase dispersity on the flotation process [15]. The quantitative chemical and mineralogical analysis he conducted, including collaborative work with N. Kurnakov [28], enabled the determination of structural features and surface properties of various types of mineral raw materials. K. F. Beloglazov is widely recognized as the author of the kinetic theory of the flotation process [15, 29, 30]. Flotation is based on the wetting of mineral (or waste rock) surfaces by water [29, 30]. Therefore, by studying flotation, Beloglazov essentially characterized the hydrophilic properties of waste rock surfaces and the hydrophobic properties of the target substance, which floated to the solution's surface. His works on the adsorption of water vapor and organic substances by clays, as well as on carbon dioxide adsorption during flotation, are well known [15, 18].

It is worth recalling that when K. F. Beloglazov began his work at the Mining Institute as an assistant to N. S. Kurnakov (1914–1917), P. P. Weimarn was already a professor in the Department of Physical Chemistry. Modern experts regard Weimarn as a founder of the science of nanotechnology [12, 25, 26], a recognition based on his development of "dispersoidology" – science whose subject matter aligns with the objects of 21st century nanotechnology [22].

According to Weimarn, "dispersoidology" is the science on properties of surfaces and the processes occurring on them. The primary object of study is the "dispersoid", a solid-phase particle with a size of less than 0,1 μm (100 nm) [12, 31]. K. F. Beloglazov also studied dispersed substances, but his work typically focused not on pure substances (sulfates, oxides, metals), as was the case in the research of his senior colleague [22], but on technically significant dispersed systems used in the mining and non-ferrous metallurgy industries [6, 15, 16]. By investigating such systems, K. F. Beloglazov skillfully applied the approaches of N. S. Kurnakov's physicochemical analysis method to complex heterogeneous systems relevant to industry.

The scientific trajectories of P. P. Weimarn and K. F. Beloglazov reveal points of intersection, particularly in their early years – during their studies at the Mining Institute and their initial years as department members. Their earliest scientific works were related to salts and water-salt systems [22, 28]. Both received Professor K. I. Lisenko's prize for their student research. In 1927, K. F. Beloglazov was appointed professor of physical chemistry and gold metallurgy. From 1941 to 1951, he headed the Department of General and Physical Chemistry. Thus, Beloglazov first became a professor and later the head of the very department that Weimarn had founded – the first professor of physical chemistry (1908–1919) at the Saint Petersburg Mining Institute [12, 22, 26].

After 1917, K. F. Beloglazov's scientific activities were multifaceted, covering a wide range of development of theoretical foundations and technological processes for the beneficiation and metallurgical processing of non-ferrous metal ores [13, 15, 16]. However, an integral part of his research was the study of surface properties and the dispersity of minerals. In 1926, he proposed a method for determining the exposed surface of chalcopyrite by treating it with an acidic sodium sulfite solution [18]. In 1936–1937, he developed a technique for quantitatively assessing the distribution of copper between free carbonate grains and highly dispersed carbonate inclusions in silicates [16]. While studying the flotation process, the scientist was the first to establish a mathematical relationship between flotation activity and various flotation parameters, including the surface properties of mineral particles and their affinity (attachment strength) to gas bubbles [16, 29, 30].

K. F. Beloglazov's scientific work was always aimed at solving pressing issues in the national economy, with a focus on the physical chemistry of mineral processing [15, 32]. He worked and led research teams not only at the Saint Petersburg Mining Institute (SPMI) but also at the Institute of Physicochemical Analysis of the USSR Academy of Sciences (1916–1919), the Mekhanobr Institute (1922–1947), and other research institutes in Leningrad [16]. From 1934, he was a member of the metallurgy group at the Mining Institute, which undertook several important industrial projects. For his series of works on the utilization of sulfide copper-nickel ores and the extraction of non-ferrous and noble metals, he was awarded the Stalin Prize, First Class (1943, as part of a team). His research, in particular, enabled the production of the first nickel from the copper-nickel ores of the Monche-Tundra deposit [6, 18].

Interestingly, the honors diploma awarded to K. F. Beloglazov on August 28, 1914, upon completing the full course at the Empress Catherine II Mining University – which noted his diploma work in chemistry – was signed by Ivan Schroeder and Peter Weimarn, therefore launching the young researcher's scientific career (**Fig. 4**)[3].

As was previously mentioned, physical chemistry held a prominent place in K. F. Beloglazov's scientific interests. It is no coincidence that in a modern review of the scientific schools of the Faculty of Chemistry and Metallurgy at the Saint Petersburg Mining University, he is described

[3]Professor I.F. Schroeder, served as Director of the Saint Petersburg Mining Institute (SPMI) from 1912 to 1917, while P.P. Weimarn acted as his closest assistant and held the position of Institute Inspector for the Student Authority [11].

ДИПЛОМЪ.

Отлично окончивший полный курсъ въ Горномъ Институтѣ Императрицы ЕКАТЕРИНЫ II
по заводскому разряду, выполнилъ дипломную работу по Химіи
студентъ БѢЛОГЛАЗОВЪ, Константинъ, оказалъ познанія:

На основаніи § 20-го ВЫСОЧАЙШЕ утвержденнаго 18-го Марта 1906 г. положенія о Горномъ Институтѣ ИМПЕРАТРИЦЫ ЕКАТЕРИНЫ II,
Бѣлоглазовъ, Константинъ, удостоивается званія горнаго инженера.
Въ удостовѣреніе чего и данъ сей дипломъ отъ Совѣта Горнаго Института ИМПЕРАТРИЦЫ ЕКАТЕРИНЫ II, за надлежащими
подписями и съ приложеніемъ большой печати Института, 29-го дня 1914 года.

Директоръ
Инспекторъ
Секретарь Совѣта

Fig. 4. Diploma of K.F. Beloglazov on graduation (*SPMI, Mining University Archives. File №. 10. Leningrad Mining Institute, Department of Human Resources. P. 25*)

as a physicochemist and specialist in the use of non-ferrous metal ores, who developed the theory of the flotation process [6, 32].

P.P. Weimarn graduated from the Mining Institute in 1908 at the age of 28. Like K. Beloglazov, he completed his studies with honors [22] under the metallurgical specialization track. Notably, his required mining plant project was substituted with a chemistry diploma thesis in recognition of his demonstrated exceptional capabilities in this scientific discipline. After 1916, their scientific trajectories and geographical locations diverged significantly. K. F. Beloglazov remained at the Mining Institute in Petrograd (later Leningrad). P. P. Weimarn became the first rector of the Ural Mining Institute in Yekaterinburg, evacuated with the institute to Vladivostok in 1919, where he served as vice-rector and later rector of the Polytechnic Institute. In 1922, he emigrated to Japan, where he worked successfully at universities in Osaka, Kyoto, Tohoku, and others, advancing the methods of dispersoidology and applying them in industry [12, 22, 25].

From an official standpoint, the highest honor awarded to K. F. Beloglazov was the Stalin Prize (1943), which he received at the age of 56. P. P. Weimarn, working in Japan, was awarded the prestigious Leonardo Prize by the German Colloid Society at the age of 53 (1932). This further solidified his international recognition, which had already been established through over 200 publications in renowned foreign journals [12, 22, 33].

The scientific careers of these two talented scholars of academician N. S. Kurnakov took markedly different paths. K. F. Beloglazov worked tirelessly until the end of his life, contributing significantly to the development of the mining and metallurgical industry in his homeland. P. P. Weimarn, in Russia, primarily focused on basic research of world level [12, 33]. Fleeing first the "Red Terror" and later the "White Terror", he was forced to leave Russia. In Japan, he quickly demonstrated the exceptional qualifications of a Russian scientist, whose work surpassed the results of his Japanese and Western colleagues [22, 33, 34]. This affirmed the global priority of Russian science and the Saint Petersburg Mining Institute (now University) in the synthesis of ultra- and nanodispersed materials. The term "nanotechnology" itself entered scientific usage only in 1974 [12, 25], which is why neither scientist used the prefix "nano-" in their work. Nevertheless, Weimarn's research on producing solids of any degree of dispersity, "starting from the molecular level" [35–37], and Beloglazov's studies on substance adsorption and flotation mechanisms [27, 29] laid the scientific foundation for the modern nanotechnology approach [12, 22, 25]. To some extent, their work anticipated the now popular sol-gel method in nanotechnology [38, 39].

Weimarn's developments in producing and stabilizing nanodispersed gold [35] and Beloglazov's work on extracting gold and platinum-group metals [6, 29] proved valuable for creating new methods to afterextract of ultrafine gold from industrial solutions at mining and metallurgical enterprises [40]. Their experience in studying the adsorption of water vapor, organic and other substances on oxide substrates (Beloglazov) and stabilizing nanosized structures in various dispersion media (Weimarn) remains relevant for the technology of producing inorganic and hybrid materials, including dispersed ones, via molecular layering [41]. This method, proposed in the USSR by V. B. Aleskovsky, gained widespread development and is better known in the West as "Atomic Layer Deposition" (ALD) [12, 25, 42].

The research of K. F. Beloglazov and P. P. Weimarn at the Mining Institute (1910–1916) on the morphology and surface properties of solids, using tools such as Sigmund's ultramicroscope with a resolution of 3–5 nm [6, 31, 36], remains relevant today. Leading global scientific schools in the 21st century continue to study the properties, control methods, and synthesis of nanosized structures, including through plasma nanotechnology [43–45].

I. N. Beloglazov

From 2004 to 2011, professor Ilya N. Beloglazov of SPMI, a representative of the Beloglazov scientific dynasty, made significant contributions to research in the field officially designated as "Nanotechnology" [15, 16, 24].

His primary activities were associated with supporting the scientific seminar "Nanophysics and Nanomaterials" (N&N), in which he actively participated (**Figs. 5–7**). He also facilitated the presentation of the Mining Institute's scientific developments at national and international exhibitions, successfully executed several publishing projects on nanotechnology, including at the international level.

I. N. Beloglazov was an encyclopedic scientist with diverse scientific interests. As noted in [15], he published works in metallurgy, chemistry, mathematics, and physics. To this, we must add his collaborative work with professor

Fig. 5. Scientific seminar "Nanophysics and Nanomaterials" (N&N) 2005. Professor I. N. Beloglazov is on the left (smiling); Professor A. G. Syrkov in the center; postgraduate student A. N. Popova, Scientific Secretary of the meeting (now Candidate of Sciences), is on the right (*Photo from A. G. Syrkov's personal archive*)

Fig. 6. Professor I. N. Beloglazov opens the meeting of the scientific seminar N&N-2006. On the blackboard is a fragment of the scheme of the "framework" hypothesis of V. B. Aleskovsky (*Photo from A. G. Syrkov's personal archive*)

A. G. Syrkov on nanotechnology [23, 24] (**Table**). By training, he was a metallurgist, graduated with honors from the Metallurgical Faculty of the Mining Institute in 1972 [16, 17]. He defended his candidate thesis in "Metallurgy of Non-Ferrous and Ferrous Metals" (1974). His doctoral thesis further broadened his research range, as it encompassed two specialties: "Metallurgy of Non-Ferrous and Ferrous Metals" and "Processes and Apparatus of Chemical Technology". In this work, he also demonstrated his prowess as a mathematician, developing the simplex method and implementing it in the metallurgical industry [6, 16].

His strong foundation in fundamental sciences and broad perspective allowed I. N. Beloglazov to be among the first at the Mining Institute to recognize the significance and potential of nanotechnology research and to seek like-minded colleagues in this field.

In early 2004 he visited the Department of General and Technical Physics (GTP) to consult on the study of optical properties of nanofilms. The head of GTP, professor E. I. Boguslavsky, recommended that him to contact professor A. G. Syrkov. During their conversation, Beloglazov received a copy of the textbook

Fig. 7. A photo for memory with the participants of the N&N-2006 seminar. In the center is professor Syrkov A. G.; on the left is professor Korsakov V. G.; on the right (one person over) is professor Beloglazov I. N.; on the podium and to the left (3 people) are future PhD candidates (Kamalova T. G., Remzova E. V.) and Doctor of Sciences (Pshchelko N. S.) in nanotechnology. (*Photo from A. G. Syrkov's personal archive*)

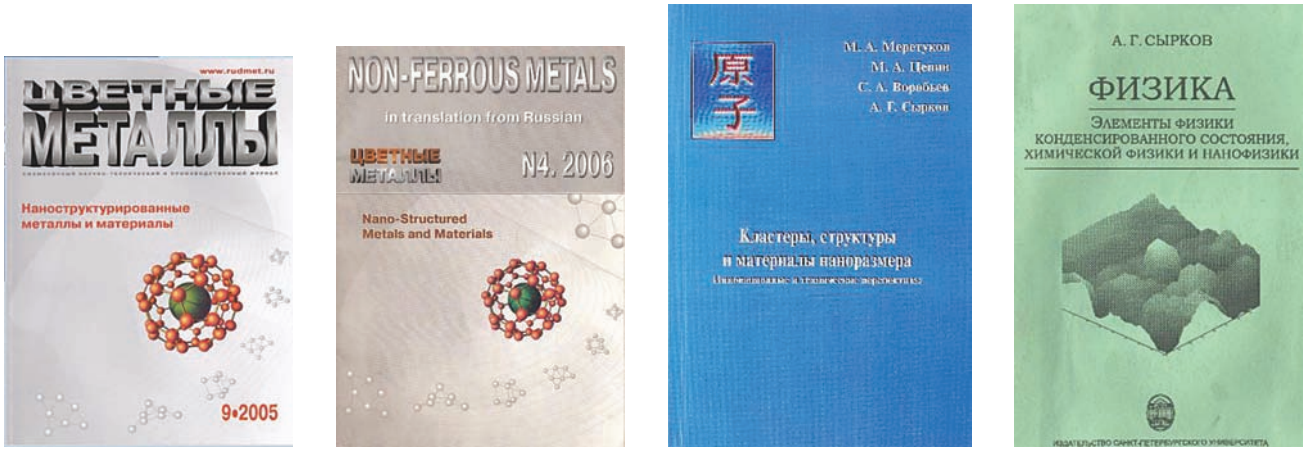
Table
The contribution of Professor of the Mining University I. N. Beloglazov to the Development of Nanotechnologies

Activities and Outcomes	Year(s)
Writing and publication* of two special themed issues on nanostructured metals and materials (**Fig. 8, *a*, *b***) based on Tsvetnye Metally journal (Moscow)	2005–2006
Organization of the publication of A. G. Syrkov's textbook on nanophysics by Saint Petersburg University Press (**Fig. 8, *d***)	2005
Writing and editing of the scientific monograph "Clusters, structures and materials of nano-dimension: innovative and technical prospects" (**Fig. 8, *c***)*	2005
Writing and publication of articles in Tsvetnye Metally journal on nanostructured metals [23, 24]*	2005–2007
Creating opportunities for research teams and organizing demonstrations of their gold medal-winning developments at the St. Petersburg Technical Fair.	2007–2010
Establishment of the "Nanotechnologies" section at the International Forum-Contest of Young Researchers "Topical Issues of Rational Use of Natural Resources"; provision of laboratory facilities to the winning team in competition of the International Fund "Generation"	2009–2011
Publication of the book "Chemical-Physical Foundations and Methods for Producing Surface-Nanostructured Metals" by I. N. Beloglazov and A. G. Syrkov, Saint Petersburg University Press	2011
*Joint project of the Mining Institute (University) and the "Ore and Metals" Publishing House.	

"Physics and Chemistry in Nanotechnology" as a gift, and Syrkov was invited to write an article on the fundamental principles of metal nanotechnology for the *Tsvetnye Metally* journal (No. 4, 2004). This marked the beginning of a highly productive collaboration between the GTP and the Department of Process and Production Automation (PPA). Soon after, two remarkable projects were realized, and special thematic issues were published in Russian (2005) and English (2006) in collaboration with the "Ore and Metals" Publishing House (Moscow) (**Fig. 8, *a, b***).In 2005, one of Russia's first scientific monographs on nanotechnology, "Clusters, structures and materials of nano-dimension: innovative and technical prospects", edited by I. N. Beloglazov, was published (**Fig. w8, *c***). To accelerate students' involvement in nanotechnology education during their physics coursework, he organized the rapid publication of the textbook "Physics: Elements of Condensed Matter Physics, Chemical Physics, and Nanophysics" (2005) (**Fig. 8, *d***).

In 2006, I. N. Beloglazov was appointed as dean of the Faculty of Fundamental and Humanitarian Disciplines, which included the GTP department. Since he remained head of PPA department, this arrangement was favorable for recruiting assistants and graduate students from the metallurgical faculty to work under A. G. Syrkov's leadership. Syrkov, while teaching physics to PPA students in their first three years – using materials from the textbook on nanophysics and quantum mechanics (**Fig. 8, *d***) – selected the most capable students for nanotechnology research at GTP (notably, Beloglazov consistently supported these candidates and provided personal recommendations for their admission to graduate programs).

As dean, I. N. Beloglazov placed special emphasis on preparing scientific developments in nanostructured metals and coatings for demonstration at prestigious scientific and technical exhibitions and congresses, including international ones. The first honorary diplomas and medals from these exhibitions were awarded in 2007. **Fig. 9** shows scanned diplomas from 2007–2010, highlighting the merits of the medals. The period from 2008 to 2010 was particularly productive, with the Mining Institute's scientific



a *b* *c* *d*

Fig. 8. Journals (*a*, *b*) and books (*c*, *d*), published in 2005–2006 with the assistance or under the editorship of professor I. N. Beloglazov

Fig. 9. Diplomas for scientific developments in nanotechnology (2007–2010) awarded with gold and silver medals

developments earning 12 medals, 7 of which were gold. International exhibitions were held in Moscow, Saint Petersburg, Taipei, Nuremberg, Geneva, and other major cities worldwide. The surge in innovation activity, in our view, was driven by the Russian government's allocation of RUB 130 million (Decree No. 498, 2008) to establish a Scientific and Educational Center for Nanotechnology at the Mining Institute. Professor I. N. Beloglazov was appointed its scientific head. New equipment, including a Jeol atomic-force microscope (Japan), was acquired, and research productivity in nanotechnology increased.

The year 2009 was marked by several important events. A new "Nanotechnology" section was introduced at the International Forum-Contest of Young Researchers "Topical Issues of Rational Use of Natural Resources", traditionally held annually at the Mining Institute (**Fig. 10, *a***). Young researchers from Austria, Germany, Poland, Belarus, Ukraine, Russia, and other countries actively participated. In December 2009, the first candidate thesis on nanostructured metals was defended. D. S. Bystrov, a graduate of the Metallurgical Faculty of the Mining Institute, defended his thesis "Nanostructural Regulation of the Reactivity and Antifriction Properties of Aluminum and Steel Surfaces" at the Technological Institute. Professor I. N. Beloglazov served as one of the opponents. In 2009, the first article from the Mining Institute appeared in the *Russian Nanotechnologies* journal, titled "Electrophysical and Chemical-Physical Micro- and Nanotechnologies for Enhancing Adhesion in Metal-Dielectric Systems" (N. S. Pshchelko, A. G. Syrkov, T. G. Vakhreneva, and others). The research was conducted under Grant No.1.4.09, "Investigation of the Patterns of Nanostructure Synthesis, Properties of Synthesized and Natural Nano-Objects, and Justification of Priority Directions for Their Use in the Mining and Processing Industry" (scientific head – professor I. N. Beloglazov). That same year, Ilya Beloglazov allocated laboratory space in study room 6103 of his department to A. G. Syrkov's research group for thesis work and funded projects. This provided crucial support for six graduate students, one doctoral candidate, and several students (professor's assistants) (**Fig. 10, *b–d***).

New scientific results and achievements soon followed. In 2011, the first prizes from the International Fund "Generation" (Andrey Skoch's fund) were awarded in two categories: "Best scientific team" (**Fig. 10, *c***) and "Best Young Scientist" in nanomaterials and nanotechnology (**Fig. 10, *d***). In 2010, I. V. Pantyushin, a PPA graduate (A. G. Syrkov's postgraduate), defended his thesis "Solid-State Synthesis of Surface-Nanostructured Metals (Ni, Cu, Al) via Adsorption Modification". In 2011, N. S. Pshchelko defended the first doctoral thesis in nanotechnology completed at the Mining Institute. This work paved the way for other doctoral theses at the Saint Petersburg Mining University (V. Yu. Bazhin, K. V. Gogolinsky, F. Yu. Sharikov, and others), addressing critical scientific problems in the synthesis and study of nanomaterials.

I. N. Beloglazov was approachable, amiable, and not only a talented scientist but also an exceptional organizer of scientific, educational, and publishing projects. He never insisted on being listed as a co-author in articles, inventions, or books related to projects he supported. The interests of the work always came first. In November 2011, when I. N. Beloglazov was seriously ill and could no longer work at the Mining University in person, he found the strength to review the abstract of N. S. Pshchelko's doctoral thesis and stay informed about the research of the Scientific and Educational Center for Nanotechnology.

I. N. Beloglazov's scientific interests were extraordinarily broad: metallurgy, chemical technology, production automation, oil and gas processing, nanotechnology, and more. Yet, in all his research, he consistently applied mathematics and advancements in fundamental sciences, including physical chemistry [46, 47]. This approach aligns his scientific style with that of K. F. Beloglazov. A similar methodology for solving technological challenges in the mineral resource sector can be found in the work of I. N. Beloglazov's successors at the PPA, metallurgy, and GTP departments [48, 49].

After becoming dean of the Faculty of Chemistry and Metallurgy (formerly the Metallurgical Faculty) in 2010, I. N. Beloglazov continued to actively engage in the field of nanotechnology. It was in 2010–2011 that he co-authored the book on the scientific foundations of producing surface-nanostructured metals (**Table**). The book outlines the principles and regularities of solid-state hydride synthesis of metals, as well as the method of layering differently sized modifier molecules on the surfaces of nickel, copper, and iron [24, 26, 50].

The team of young researchers awarded prestigious prizes by the "Generation" Fund in 2011 primarily

Fig. 10. Events of 2009–2010 and people with whom I. N. Beloglazov worked on nanotechnology during this period:
a) opening of the section "Nanotechnology" by I. N. Beloglazov at The International Forum of Young Researchers "Topical Issues of Rational Use of Natural Resources" (2009); b) work of postgraduate student Remzova E. V. on the friction machine DM-29M in the laboratory of the department of I. N. Beloglazov (PPA), 2011; c) the winning team in the nomination "Best scientific team" in the open competition of the International Fund "Generation" (2011): from left to right: student of the department Tufrikova V. F., professor A. G. Syrkov (head of the project), postgraduate student Kamalova T. G., postgraduate student L. A. Yachmenova; d) assistant, Candidate of Chemistry Sciences Bystrov D. S. – winner in the nomination "Best Young Scientist" (from the International Fund "Generation", 2011), professor A. G. Syrkov, postgraduate students Remzova E. V., Yachmenova L. A. (now Candidates of Sciences). (*Photo from A. G. Syrkov's personal archive*)

consisted of graduates or students of the Faculty of Chemistry and Metallurgy (D. S. Bystrov, E. V. Remzova, L. A. Yachmenova, V. F. Tufrikova). The work of training graduate students and developing a pool of specialists for teaching and research in departments (PPA, GTP, etc.) working in nanotechnology-related fields has been going for a was a long-term process. This was confirmed by evidence from 2009 to 2025. Of approximately 20 theses defended on nanotechnology topics during this period, at least 10 were by graduates of the Metallurgical Faculty, including graduates of the PPA (D. S. Bystrov, I. V. Pantyushin, E. V. Remzova, A. V. Saitov, A. A. Vinogradova, M. O. Silivanov, L. A. Yachmenova, A. N. Kushchenko, D. H. Chan, V. R. Kabirov and others). Of the five young faculty members at GTP department working in the field of nanotechnology, three are graduates of the Metallurgical Faculty (two from PPA). All three studied under I. N. Beloglazov and defended their theses under A. G. Syrkov's leadership.

I. N. Beloglazov supported all those interested in nanotechnology at the Mining University but particularly emphasized three research directions led by professors A. S. Mustafaev, A. G. Syrkov, and then-associate professor V. Yu. Bazhin (now a professor). His targeted support proved justified. In 2018, A. S. Mustafaev co-authored a scientific discovery (Diploma No. 509) in the field of graphene structures and plasma nanotechnology [45]. In 2020, three nanotechnology research directions were designated as world-class scientific directions by the University Academic Council:

I. Nanostructured ligatures with rare-earth metals for producing lightweight superplastic alloys (scientific head – V. Yu. Bazhin);

II. Plasma nanotechnology and new materials in the mineral resource sector (scientific head – A. S. Mustafaev);

III. Nanostructured highly hydrophobic metals and solid-state synthesis methods (scientific head– A. G. Syrkov).

One of the potential opportunities of direction III, which has already been partially implemented in practice,

is to create very promising superhydrophobic materials, including those based on metals [51, 52]. For example, Syrkov's research group produced dispersed metals (Fe, Ni, Cu) exhibiting minimal water molecule adsorption (0,1 monolayer) in saturated H_2O vapor [24, 26, 50]. The total number of medals awarded to these three directions from 2008 to 2011 was at least 20. In recent years, this number has doubled, with the essence of award-winning nanotechnology developments (2003–2024) reported annually at the International Symposium N&N [45, 50, 53].

Conclusions

Honored Workers of Science and Engineering, professors K. F. Beloglazov and I. N. Beloglazov, members of the renowned Beloglazovs-Thiemes dynasty of mining engineers and metallurgists, advanced the research of academician N. S. Kurnakov's scientific school, focusing on highly and nanodispersed systems (materials). K. F. Beloglazov conducted extensive studies on the microstructure and quantitative chemical-mineralogical analysis of alloys and minerals. He systematically investigated the adsorption of various substances by clays and during flotation, deriving an equation for calculating the surface energy of binary solutions. He developed the theory and derived a kinetic equation for the flotation process, accounting for the dispersity and surface properties of minerals. While addressing complex industrial challenges, including technologies for the Norilsk Mining and Metallurgical Plant, K. F. Beloglazov consistently applied physicochemical analysis, considering the influence of mineral surface dispersity and structure. His research extended the pioneering work of P. P. Weimarn in highly and ultra-dispersed systems, including nano-objects studied in the 21st century.

Leading nanotechnology research at the Saint Petersburg Mining University, I. N. Beloglazov furthered the study of surface phenomena physical chemistry. Collaborating with A. G. Syrkov, he developed solid-state synthesis methods for nanostructured metals, implemented at mining and chemical enterprises of the Union State. I. N. Beloglazov wrote and co-edited two books on nanoscale systems, and the projects he supervised earned 20 medals at international exhibitions. Thanks in part to his efforts, the Saint Petersburg Mining University joined Russia's National Nanotechnology Network (NNN) and contributed to the Presidential Program in Nanotechnology.

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