

ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казакский национальный исследовательский
технический университет им. К. И. Сатпаева

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Kazakh national research technical university
named after K. I. Satpayev

**SERIES
OF GEOLOGY AND TECHNICAL SCIENCES**

3 (435)

MAY – JUNE 2019

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

Б а с р е д а к т о р ы
э. ғ. д., профессор, ҚР ҰҒА академигі

И.К. Бейсембетов

Бас редакторының орынбасары

Жолтаев Г.Ж. проф., геол.-мин. ғ. докторы

Р е д а к ц и я а л қ а с ы:

Абаканов Т.Д. проф. (Қазақстан)
Абишева З.С. проф., академик (Қазақстан)
Агабеков В.Е. академик (Беларусь)
Алиев Т. проф., академик (Әзірбайжан)
Бакиров А.Б. проф., (Қырғыстан)
Беспәев Х.А. проф. (Қазақстан)
Бишимбаев В.К. проф., академик (Қазақстан)
Буктуков Н.С. проф., академик (Қазақстан)
Булат А.Ф. проф., академик (Украина)
Ганиев И.Н. проф., академик (Тәжікстан)
Грэвис Р.М. проф. (АҚШ)
Ерғалиев Г.К. проф., академик (Қазақстан)
Жуков Н.М. проф. (Қазақстан)
Қожахметов С.М. проф., академик (Қазақстан)
Конторович А.Э. проф., академик (Ресей)
Курскеев А.К. проф., академик (Қазақстан)
Курчавов А.М. проф., (Ресей)
Медеу А.Р. проф., академик (Қазақстан)
Мұхамеджанов М.А. проф., корр.-мүшесі (Қазақстан)
Нигматова С.А. проф. (Қазақстан)
Оздоев С.М. проф., академик (Қазақстан)
Постолатий В. проф., академик (Молдова)
Ракишев Б.Р. проф., академик (Қазақстан)
Сейтов Н.С. проф., корр.-мүшесі (Қазақстан)
Сейтмуратова Э.Ю. проф., корр.-мүшесі (Қазақстан)
Степанец В.Г. проф., (Германия)
Хамфери Дж.Д. проф. (АҚШ)
Штейнер М. проф. (Германия)

«ҚР ҰҒА Хабарлары. Геология мен техникалық ғылымдар сериясы».

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде
30.04.2010 ж. берілген №10892-Ж мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18,
<http://www.geolog-technical.kz/index.php/en/>

© Қазақстан Республикасының Ұлттық ғылым академиясы, 2019

Редакцияның Қазақстан, 050010, Алматы қ., Қабанбай батыра көш., 69а.

мекенжайы: Қ. И. Сәтбаев атындағы геология ғылымдар институты, 334 бөлме. Тел.: 291-59-38.

Типографияның мекенжайы: «Аруна» ЖК, Алматы қ., Муратбаева көш., 75.

Г л а в н ы й р е д а к т о р
д. э. н., профессор, академик НАН РК

И. К. Бейсембетов

Заместитель главного редактора

Жолтаев Г.Ж. проф., доктор геол.-мин. наук

Р е д а к ц и о н н а я к о л л е г и я:

Абаканов Т.Д. проф. (Казахстан)
Абишева З.С. проф., академик (Казахстан)
Агабеков В.Е. академик (Беларусь)
Алиев Т. проф., академик (Азербайджан)
Бакиров А.Б. проф., (Кыргызстан)
Беспаяев Х.А. проф. (Казахстан)
Бишимбаев В.К. проф., академик (Казахстан)
Буктуков Н.С. проф., академик (Казахстан)
Булат А.Ф. проф., академик (Украина)
Ганиев И.Н. проф., академик (Таджикистан)
Грэвис Р.М. проф. (США)
Ергалиев Г.К. проф., академик (Казахстан)
Жуков Н.М. проф. (Казахстан)
Кожаметов С.М. проф., академик (Казахстан)
Конторович А.Э. проф., академик (Россия)
Курскеев А.К. проф., академик (Казахстан)
Курчавов А.М. проф., (Россия)
Медеу А.Р. проф., академик (Казахстан)
Мухамеджанов М.А. проф., чл.-корр. (Казахстан)
Нигматова С.А. проф. (Казахстан)
Оздоев С.М. проф., академик (Казахстан)
Постолатий В. проф., академик (Молдова)
Ракишев Б.Р. проф., академик (Казахстан)
Сейтов Н.С. проф., чл.-корр. (Казахстан)
Сейтмуратова Э.Ю. проф., чл.-корр. (Казахстан)
Степанец В.Г. проф., (Германия)
Хамфери Дж.Д. проф. (США)
Штейнер М. проф. (Германия)

«Известия НАН РК. Серия геологии и технических наук».

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан (г. Алматы)

Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан №10892-Ж, выданное 30.04.2010 г.

Периодичность: 6 раз в год

Тираж: 300 экземпляров

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
<http://nauka-nanrk.kz/geology-technical.kz>

© Национальная академия наук Республики Казахстан, 2019

Адрес редакции: Казахстан, 050010, г. Алматы, ул. Кабанбай батыра, 69а.

Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75

E d i t o r i n c h i e f

doctor of Economics, professor, academician of NAS RK

I. K. Beisembetov

Deputy editor in chief

Zholtayev G.Zh. prof., dr. geol-min. sc.

E d i t o r i a l b o a r d:

Abakanov T.D. prof. (Kazakhstan)
Abisheva Z.S. prof., academician (Kazakhstan)
Agabekov V.Ye. academician (Belarus)
Aliyev T. prof., academician (Azerbaijan)
Bakirov A.B. prof., (Kyrgyzstan)
Bespayev Kh.A. prof. (Kazakhstan)
Bishimbayev V.K. prof., academician (Kazakhstan)
Buktukov N.S. prof., academician (Kazakhstan)
Bulat A.F. prof., academician (Ukraine)
Ganiyev I.N. prof., academician (Tadjikistan)
Gravis R.M. prof. (USA)
Yergaliev G.K. prof., academician (Kazakhstan)
Zhukov N.M. prof. (Kazakhstan)
Kozhakhmetov S.M. prof., academician (Kazakhstan)
Kontorovich A.Ye. prof., academician (Russia)
Kurskeyev A.K. prof., academician (Kazakhstan)
Kurchavov A.M. prof., (Russia)
Medeu A.R. prof., academician (Kazakhstan)
Muhamedzhanov M.A. prof., corr. member. (Kazakhstan)
Nigmatova S.A. prof. (Kazakhstan)
Ozdoev S.M. prof., academician (Kazakhstan)
Postolatii V. prof., academician (Moldova)
Rakishev B.R. prof., academician (Kazakhstan)
Seitov N.S. prof., corr. member. (Kazakhstan)
Seitmuratova Ye.U. prof., corr. member. (Kazakhstan)
Stepanets V.G. prof., (Germany)
Humphery G.D. prof. (USA)
Steiner M. prof. (Germany)

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)

The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 10892-Ж, issued 30.04.2010

Periodicity: 6 times a year

Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18,
<http://nauka-nanrk.kz/geology-technical.kz>

© National Academy of Sciences of the Republic of Kazakhstan, 2019

Editorial address: Institute of Geological Sciences named after K.I. Satpayev
69a, Kabanbai batyr str., of. 334, Almaty, 050010, Kazakhstan, tel.: 291-59-38.

Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

NEWS

OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN

SERIES OF GEOLOGY AND TECHNICAL SCIENCES

ISSN 2224-5278

Volume 3, Number 435 (2019), 189 – 202

<https://doi.org/10.32014/2019.2518-170X.85>

УДК 620.3

A. A. Kalybay¹, B. B. Teltayev¹, A. K. Abzhaliyev²¹JSC “Kazakhstan Highway Research Institute”, Almaty, Kazakhstan,²Department of Physics, University of Calgary, Calgary, Canada.

E-mail: ao_kazdormii@mail.ru, bagdatbt@yahoo.com, abulkhair.abzhali@gmail.com

**NANOENERGETIC MATERIALS
AND LOW-CARBON NANOENERGETICS:
REGULARITIES, TECHNOLOGY AND RAW PRODUCTS**

Abstract. Physical, physicochemical, and chemical laws have been discovered and studied, and the technology of energy efficient production from substances (carbon, metal oxides, salts and minerals) that make up low-grade coal rocks has been substantiated:

– nanoenergetic materials (nanocarbon, nanopowders of silicon, aluminum, titanium, iron, manganese, magnesium, etc.);

– low-carbon liquid fuel which is environmentally friendly, of high-calorific quality comparable to natural gas, but safe, is much cheaper in price and convenient for transportation and storage in comparison with gas. It has been established that the sizes of nanoparticles of abrasion, microcracks and nanopores of rocks are critical technological parameters of the energy efficient production of nanoenergetic materials and the development of low-carbon nanoenergetics.

Key words: low grade coal rock, ash content, cracks and micropores of micron-nanodimensions, physical field, vacuum, discharge shock waves, hydroconversion, dry conversion, strength of internal and external electric and magnetic fields.

Introduction. Addressing to the American Physical Society in December 1959, Prof. Richard Feynman, the Nobel Prize winner in Physics, spoke about the possibility of creating “defect-free substances at the atomic-molecular level”. The scientific community considers him as the founder of science about nanosubstances studying development and interaction regularities of nanoparticles, their agglomerates and structures [1]. In 1974 the term “nanotechnology” was defined as “separation, consolidation and deformation of materials by one atom or by one molecule” by Norio Taniguchi, Tokyo Science University Professor, in his paper, “On the Basic Concept of Nanotechnology” [2, 3]. The current concept of nanotechnology lies in programmed manipulation of individual molecules and atoms, in controlled regulation of the structure and composition of various nanomaterials with sizes determining qualitative and other fundamental parameters, properties and areas of their use [4, 5]. Nanotechnology is divided into groups by production methods [1-5]:

- powder metallurgy (electro-discharge sintering; gas-phase deposition and compaction);
- plastic deformation (shock effects; equal-channel angular pressing);
- amorphization (crystallization from the amorphous state; sol-gel synthesis, peptide synthesis);
- film coating (chemical and physical deposition of coating from the gas phase);
- nanocarbon technology;
- machine (nanorobots; molecular assemblies; self-replicating nanomachines);
- bioengineering (complexes of nanoparticles and surface DNA molecules, nanoparticles, layers of liquid crystals and surface DNA molecules, living cells; transformation of ordinary cells into stem cells replicating to human organs).

USA, China and Japan occupy the leading positions in nanotechnology and nanoindustry starting their research in the 80s of the last century. They are the first countries to start national programs such as the Japan's "National Program of Work on Nanotechnology" in 1999, USA's "National Nanotechnology Initiative" in 2000 and China's "National Program of the Development of Nanotechnology for the period from 2001 to 2006" in 2001 (extended to 2030). With a slight delay, nanotechnological programs were also adopted by the European Union (2003) and the Russian Federation (2005). To date, more than 30 countries have adopted similar programs. In general, nanotechnology is becoming a cross-cutting way of the development of the world economy, defense, security and environmental well-being on the planet. The market of nano-goods, being a little more than 2.5 billion US dollars in 2000, exceeded 30 billion US dollars and achieved an annual increase of almost 15%. According to the forecast of the National Science Foundation of the USA, nanoelectronics will take the lead in sales in the coming years occupying at least 40% of the volume of global nanoindustry goods.

The rapid growth of the market of nanoindustry products is caused by significant improvements in their production technology, consumer qualities and properties, a decrease in the cost and price of nano-products due to the replication of similar products by additive 3D printing. In this regard, the availability of affordable raw materials and energy resources, energy-efficient technology and devices which implement it (equipment, apparatus, reactors, etc.) is of particular relevance for the production of nano-materials [1-5].

Considering the absence of the unambiguous term "nanomaterial" let us call a particle with linear dimensions varying from 1 nanometer (**nm**) to 30 nm as a **nanoparticle**, and also let us call a nanoparticle with an ordered arrangement of atoms and ions as a **nanocrystallite**. **Nanomaterials** are dispersed materials with structural elements (nanoparticles, nanocrystallites, their blocks and clusters) having nanosizes from 1 nm to 10 nm in one or two dimensions, qualitatively new physical (weight, strength, electrical conductivity, thermal conductivity, etc.), chemical (bond energy, degree of freedom, conditional valence, etc.), functional and operational properties and characteristics [4,5]. These definitions can be attributed to nanoenergetic materials; nanoparticles of carbon, silicon, electrically conductive metals, nanocarbon tubes, uncoated and coated with electrically conductive layers of photoelectric nanocrystallites in particular.

Raw products for nanoenergetic materials and low-carbon nanoenergetics. We consider low-grade (energetic) coal rocks with medium (up to 25% and less) and large (from 25% and above) ash content as the main raw material for the production of nano-energy materials. According to the "BP Statistical Review of World Energy" Kazakhstan has the reliably established coal reserve of 34.02 billion tons and is ranked as the ninth in the world. According to the statistics from the Energy Information Administration of the United States Kazakhstan is ranked as the ninth in terms of annual coal production (115 million tons per year). At the same time, only 10% of Kazakhstan's coal reserves are related to coking coal, and its annual production exceeds 30 million tons with 22 million tons being exported to the Russian Federation (the Ministry of Energy of the Republic of Kazakhstan statistics).

Thus, the bulk of coal in Kazakhstan belongs to high-ash energetic coal which needs to be revealed in its energy-chemical, metallogenic and mineral potentials. Let us consider the chemical composition of the ash (in % of mass) of energetic coals:

– medium ash (ash content of 20.5%) of the Shoptykol deposit, the Maykuba mine – 45.53% SiO₂; 21.63% Al₂O₃; 14.75% Fe₂O₃; 5.25% CaO; 2.86% MgO; 1.72% Na₂O; 1.90% K₂O; 4.25% PbO₃; 0.91% TiO₂ 0.78% P₂O₅; 0.50% SO₃;

– high ash (ash content of 34.43%) of the Saryadyr deposit, the Nadezhnyi reservoir – 65.88% SiO₂; 30.03% Al₂O₃; 1.56% Fe₂O₃; 0.14% CaO; 0.05% MgO; 0.54% Na₂O; 0.14% K₂O; 0.89% TiO₂; 0.53% P₂O₅; 0.21% SO₃.

These compositions of ash are characteristic for the majority of medium and high ash coal used in the energy sector and housing services. Note that the minerals of the Shoptykol and Saryadyr deposits having 53.27 and 33.88% of metal content each together with silica make up 98.80 and 99.76% of the mass of their ash possess large metallogenic and mineral potentials. The specific capital expenditures for the development of coal deposits including the extraction, transportation and preparation of commercial coal are significantly lower than the corresponding costs for the development of oil, oil and gas and gas deposits. Consequently, the development of coal deposits with low operating costs forms an attractive

business model with a rapid turnover of capital, accelerated payback and a long-term perspective. This justifies the choice of low-grade coal as a raw material for the production of nanoenergetic materials and the creation of low-carbon nanoenergy.

Solar photoenergy whose electric generating devices can be connected to the public grid (**on-grid**) and work without such a connection (**off-grid**) uses a large number of solar cells. These elements called crystalline (85-90%) and thin-film (10-15%) silicon are made of “solar” silicon with a purity of 99.9999% (6N) per mass (solar-grade silicon **SoG-Si**) in its turn obtained from metallurgical (technical) silicon of purity of 96-98% of mass (metallurgical-grade silicon **MG-Si**). The raw material for obtaining of MG-Si is silica the content of which in low-grade coal rocks of the Saryadyr deposit is about 66% of the ash mass. MG-Si is obtained from silica by carbothermic reduction using coal from expensive wood sorts with qualitative characteristics (table 1):

Table 1 – Charcoal indicators in accordance with GOST 7657-84

Name of indicators	Brand “A”	Brand “B”
	1st grade	1st grade
1. Mass fraction of ash, %, not more than	3.0	2.5
2. Mass fraction of non-volatile carbon, %, not less than	78	88
3. Mass fraction of water, %, no more than	6	6
4. Mass fraction of coal with grains at loading sites, %, less than 12 mm	5	5
5. Mass fraction of smut, %, no more than	2	absence

For comparison with the data in table 1, we provide qualitative indicators of nanocarbon of our production replacing charcoal (table 2):

Table 2 – Qualitative indicators of nanocarbon of coal from the Saryadyr deposit

Name indicators	
1. Sizes (nano)	100-200
2. Carbon content, %	92.74
3. Ash content, %	2.16
4. Volatiles, %	3.10
5. Humidity, %	2.00

Our experience in producing of MG-Si from silicon oxide of coal ash from the Saryadyr deposit using nanocarbon of our own production from the same Saryadyr coal showed a threefold decrease in cost, up to 4N (99.99% by weight) growth in purity, practical removal of phosphorus and sulfur oxides creating processing problems in obtaining of SoG-Si from MG-Si. Thus, low-grade coal rocks become the real raw material base for photo-energy which is an effective sector of the nanoindustry.

In addition, nanoelectronics uses a large volume of 9N pure electron silicon (electronic-grade silicon **EG-Si**) produced from SoG-Si by the Siemens method of high purification. Consequently, the production of electron silicon which forms the basis of nanoelectronics acquires a complete and competitive technological chain guaranteed by raw materials.

Kazakhstan spending more than 0.5 kg of energy carrier in oil equivalent to produce gross domestic product of one US dollar is in the top ten of the most energy-wasteful countries in the world. According to this indicator, Kazakhstan is behind Japan by 19 times, the European Union by 7 times and its partners in the Customs and Eurasian Economic Unions, Russia and Belarus, by 1.5 times [6,7]. Consequently, the solution of the issue of an affordable, cheap, alternative energy source on renewable sources and energy carriers with a low carbon content is of paramount importance for Kazakhstan and the whole world.

Usually, nanoenergetics is understood as the creation of energy generating devices and the production of energy on renewable energy sources, regenerated nanofuel cells, radiation concentrators, production of various energy storage devices on nanomaterials and others [1-8]. Therefore, we are turning to a new

aspect of nanoenergetics using hydrogenated nanocarbon as an energy carrier with a low carbon content and high electromagnetic energy of the electron shell of carbon atoms. It creates a niche for the environmentally friendly and high-calorific liquid coal fuel which is comparable to natural gas in qualitative parameters, safe and convenient in storage and transportation, and significantly cheaper than gas. Its high calorific value is provided by hydrogen. Nanocarbon and carbon atoms play the role of a catalyst and promoter of the combustion process. In addition, the main product of combustion is water condensed steam which produces additional thermal energy for the necessary heating of liquid coal. It should be noted that such a fuel having an internal oxidizer in the form of an oxygen hydroxide uses a minimum amount of atmospheric air and forms a much smaller number of nitrogenous compounds when burned.

Thus, the sectors of nanoindustry, the production of nanoenergetic materials and low carbon nanoenergetics obtain a single raw material base in the form of low-grade coal rocks and turn the coal industry into the real economy sector. Let us consider the question of the technological basis of the named sectors of the nanoindustry and their unity from the point of view of physical, physicochemical and chemical laws of the material world.

Technological base of nanoenergetic materials production and creation of low-carbon nanoenergetics. Nanoindustry and energetics are sharply distinguished by increased energy consumption and resource dependence respectively in the global economy. If the energy costs in the young and growing nanoindustry are compensated by its other advantages and can be overcome in the near future due to alternative energy sources, then the situation in the energy sector turns out to be quite different. Energetics, a basic industry responsible for the energy and environmental safety of the world economy, needs fundamental structural and resource transformations. *Such transformations should ensure the transition of the world economy from its natural resource form to a cyclic form on alternative to coal and hydrocarbons energy sources accessible to everyone and everywhere, having higher calorific value, ecological cleanliness and ease of transportation and storage than natural gas.*

Based on the position of full use of the potentials of low-grade coal rocks there are *two operational options for the technology of vacuum-wave conversion of coal rocks by the magnetoelectric field:*

- dry conversion with the production of carbon nanopowders, metal oxides and without the production of liquid coal fuel (LCF);
- hydroconversion with the production of metal oxide nanopowders and LFC for energetics.

The technology of vacuum-wave conversion of coal and hydrocarbon compounds by the magnetoelectric field, low-temperature and acoustic-wave effects is patented [8]. The main nanomolecular reactors that implement the conversion are also patented [9, 10]. The technology is implemented by a technological line that meets the requirements of technical specifications TU 3689-001-38281705-2012 [11] approved by the Federal Agency for Technological Regulation and Metrology of the Russian Federation. It is certified according to the international standard ISO-9001-2008 and has the Certificate of Conformity of the Russian Federation №C-RU.AG98.V.05607-TP 1457858 [12].

Coal rocks as a whole and low-grade coals in particular have multi-level heterogeneity with clearly distinguishable organic and metal-mineral constituents. According to the most adequate concepts [13] and images obtained by atomic force (SMM - 200T), scanning (SEM) and transmission (TEM) electron microscopes and X-ray diffractometer organic matter consists of non-condensed and condensed aromatic (benzene) and branched aliphatic structures [14]. Each of these structures forms pronounced **crystalline** (packet) formations with metal-mineralogical inclusions. From 3 to 7 layers with thicknesses from 1.8 nm to 4.8 nm, and the packets (crystallites) have porous-fractured structures with micro-nanopores with linear dimensions from 10^{-6} m to 10^{-9} m and a concentration from 10^{11} up to 10^{20} units in one cm^3 [14]. The characteristic values of the resistance of coal rocks to deformations do not exceed 1.5-1.7 MPa, and the coefficient of their strength (grinding ability) does not exceed 1.6 [13-15].

Condensed and unfused benzene nuclei constituting crystallites are interconnected by aliphatic threads with (C-C) bonds, weakened (C-O), (C-S), (S-S) bonds. The intercrystalline large-pore space is filled with coal gas-methane under high pressure of several tens (sometimes hundreds) of MPa and large mass. They are classified as volatile substances comprising from 30 to 40% of the mass of coal rocks. Low-grade coals have tremendous calorific value and can be considered a competitive energetic fuel due to them. Moreover, about 40% of the energy produced in the world (electrical and thermal) comes from coal's share (mostly low-grade). The resulting ash dumps await the arrival of nanotechnology and the formation of nanoindustry.

And so, coal has a characteristic chemical composition the substances of which formed crystalline formations with a layered structure of benzene nuclei and aliphatic hydrocarbons with numerous metal-mineral inclusions interconnected by electromagnetic forces. Single crystals and their agglomerates are speckled with a large number of cracks and micro-nanopores, other weakening and surface ruptures. These features of the chemical composition and structure, the electromagnetic nature of the interaction of atoms and coal molecules constitute the basic physical, physicochemical and chemical mechanisms obtaining nanomaterials and liquid low-carbon fuel of wide industrial use. These mechanisms form the technological basis of the process of vacuum-wave conversion of carbon and hydrocarbon compounds into materials and products. The arising question is how these basic mechanisms are used in the implementation of the conversion process. Answering the question we note that the coal rock withstands very large compressive forces (tens of MPa) and resists weakly the tensile forces. Consequently, the vacuum and vacuum stretching will have a far greater effect than compression. The natural way to create tensile forces is to transform static pressure into dynamic pressure according to the Bernoulli law [16, 17].

With this in mind, we consider the physical and mechanochemical aspects of forming nanosized particles of coal rocks and the electromagnetic laws of this process in a rotating electromagnetic field with an angular velocity from 50 rev/sec to 3000 rev/sec. Consequently, the linear velocity at the chamber wall with a radius of 200 mm (0.20 m) and at a radius of 150 mm (0.15 m) can reach $V_{0.2}=480$ m/s and $V_{0.15}=360$ m/s respectively. With an average density of coal rocks ρ_a equal to 1600 kg / m^3 the dynamic pressure has a value of $P_{0.2}\approx 184$ MPa on the wall and $P_{0.15}\approx 10$ MPa on a radius of 0.15 m. The layered distribution of velocities and the associated dynamic pressures indicate that the rocks are experiencing, firstly, the tensile forces of the advance layer on the layers lagging behind it; secondly, stress of at least 100 MPa is applied vertically on each layer while the reactor is also placed vertically. Rocks having a weak resistance to tensile forces begin to break down along the cracks and form new nanopores and microcracks in their smaller pieces; the process of closing the pores proceeds under the action of dynamic pressure. The gases contained in them participate in microexplosions destroying the rocks, and new nanopores and microcracks are created in their fragments [18].

Therefore, the mechanochemical regularities of Reh binder effect manifest themselves at the initial stage of the formation of particles with micrometric and nanometric sizes [18]. The factor determining the effectiveness of obtaining carbon and oximetallic nanopowders are the electric and magnetic fields of the electromagnetic interactions of particles forming surfaces of new nanopores and microcracks. Nanopores, microcracks and freshly created surfaces limiting them are formed as a result of breaking (C-C) bonds over the entire surface. Since (C-C) bonds are formed by electrons and its carbon atoms have opposite charges with the Coulomb interaction between these atoms the opposite charges concentrate on the walls of nanopores with the surface charge density ρ_e per unit surface area. Assuming that the pores have spherical radius of $r_p=10^{-6}$ m (1 micron) we calculate ρ_e for the radius of one carbon molecule C_2 , $r_c=1.243A^0$ [16]. Density $\rho_e=10^{15} \text{ e/cm}^2$ for the above values. Similar calculations for silicon, aluminum, iron and titanium give average values of ρ_e on the order of 10^{14} e/cm^2 , and it is on the order of 10^{15} e/cm^2 for sulfur, fluorine and phosphorus.

Note that ρ_e on the order of $10^{14}-10^{15} \text{ e/cm}^2$ is a sufficiently high concentration of charges capable of creating an electric field with a strength of about $E=10^7 \text{ V/cm}$ (10^9 V/m) for the known values of length $l_c=0.771 \cdot 10^{-8} \text{ cm}$ of the chemical bond between the atoms of the carbon molecule and the energy difference of the latter and its neighboring electronic levels $U_e=0.08 \text{ eV}$ [19]. An electric field with a specified intensity is able to pull out not only surface electrons, but also ones from shallow depths, forming their emission fluxes and giving them sufficiently high energies. Therefore, taking into account that the opposite charges are separated and provide a potential difference on the newly formed surfaces it is necessary to calculate the voltage U of the field in accordance with the Coulomb law for the pore radius: it will have a value of the order of 10^5 V [20]. It can be considered as an accelerating voltage, accelerating the emission electron to a velocity of about $1.875 \cdot 10^8 \text{ m/s}$. The accelerated emission electron has a kinetic energy T_e of about 10^5 eV and emits electromagnetic waves (photons) with a length of $\sim 10^{-2} \text{ nm}$ and a frequency of $\sim 10^{19} \text{ Hz}$. These high energy electrons and the photons emitted by them are involved in the further destruction of high-molecular compounds of coal rocks and having a sufficient intensity of the wave they crush the rocks to nanosized particles.

The truth of our findings must be experimentally verified. In this regard, we note that the Committee for Inventions and Council of Ministers opened under the USSR entered the State Register of Discoveries of the USSR on June 7, 1984 for No. 290 with a priority of December 3, 1952, the scientific discovery of the authors - B. Deryagin, Corresponding Member of the USSR Academy of Sciences, N.A. Krotov, Doctor of Chemistry, and V.V. Karasyov, Candidate of Physics and Mathematics, from the Institute of Physical Chemistry of the Academy of Sciences of the USSR with the discovery formula: **“Previously unknown property is experimentally established for freshly formed surfaces of solids to emit high-energy electrons in a vacuum due to the separation of opposite charges during the formation of juvenile surfaces resulting in the appearance of strong electric fields of intensity up to 10^7 V/cm”** [21].

The experimental values of I_c and U_e have been used during calculation of the electric field strength. Therefore, the intensity of 10^7 V/cm is an absolutely reliable value. The pore radius value obtained from electron microscopic studies of the porosity of coal rocks was used at determining of the surface density of charges ρ_e and field voltage. Moreover, the values we calculated for ρ_e , the energies of the emission electrons and the lengths of the frequency of electron emissions have coincided with their experimental data from the abovementioned discovery.

The selected value of the pore radius can be used in the calculations of the characteristics of the magnetic field per segment of pore radius from 10^{-9} to 10^{-6} m. Then the magnetic field strength \mathbf{H} for the pores has values from $2.4 \cdot 10^6$ to 2.4 A/m respectively. Magnetic induction \mathbf{B} ranges from 3 to $3 \cdot 10^{-2}$ T; pressure of the field P_m ranges from $3.6 \cdot 10^5$ to $3.6 \cdot 10^{-5}$ N/m², i.e. from 0.36 MPa to 0.3 μ m Hg (a fairly deep vacuum). The creation of a vacuum by the magnetic field inside the pores with a radius of 10^{-6} m is **not a random, but a regular phenomenon**. According to the discovery formula (see above), the emission of electrons occurs in a vacuum. Consequently, the electric and magnetic fields of charged particles which inhabit the surface and near-surface layers of pores work together performing their own functions [20].

In general, the formation of nanopowders of carbon, metal oxides and minerals is due to the abrasion of coal rocks. Its mechanism combines mechanochemical effects, the effects of shock waves, vacuum, electric and magnetic fields. The abrasion of coal rocks into nanopowders is a chemical reaction of breaking chemical bonds between atoms characterized by the transformation of the electron shells of molecules and the electron-nuclear magnetic interaction of atomic nuclei, ions and radicals **where electromagnetism plays the main role** and the mechanochemical effect together with the effects of shock waves and vacuum are clearly explained by electromagnetic interactions.

Calculations of the surface density of high-energy electrons, the strengths of their electric and magnetic fields and the complete coincidence of their values with experimental data from numerous experiments prove that the radius of nanoparticles serves as a critical technological parameter determining chemical and physical activity, reactivity and degree of concentration of electromagnetic energy in nanomaterials. The mutual correlation of the radii of nanopores and nanoparticles confirms the energy efficiency of producing nanomaterials from coal. Therefore, we can formulate that we have discovered a previously unknown phenomenon consisting in the concentration in these freshly-formed surfaces of the internal energy of a large amount of electric and magnetic fields of bare electrons released even with weak effects on electrons by external electric and magnetic fields and low-intensity shock and acoustic discharges.

To provide closeness and completeness of the presentation we will specify the calculated relations. **The electric field strength $E(C_2)$** of a single carbon molecule C_2 is expressed by the formula $E(C_2) = \Delta U(C_2) / eL(C_2)$, where $\Delta U(C_2)$ is the energy difference of the latter (external) and subsequent energy levels of the C_2 molecule, $L(C_2)$ is the length of its chemical bond, and e is the electron charge. Their reference values are: $\Delta U(C_2) = 0.08$ eV; $L(C_2) = 0.771 \cdot 10^{-10}$ m; $e = 1.602 \cdot 10^{-19}$ C [16, 22]. Substituting this data into the indicated formula we will have the value of $E(C_2) = 1.04 \cdot 10^9$ V/m or $E(C_2) \approx 10^7$ V/cm. It should be noted that the strength is a characteristic of the electric field of the molecule and does not depend on the cracking factor, and the voltage of such field is increased as a result of the formation of cracks and pores. Therefore, it is a function of the radius of cracks and pores by which we mean the radius r_s of the minimal sphere that completely covers the crack (pores): $U_e(r_s) = (e/4\pi\epsilon\epsilon_0)r_s^2$. Here $\epsilon = 1$, $\epsilon_0 = (1/\pi)9 \cdot 10^9$ (F/m) is the dielectric constant. We specify that we understand fractures in the medium coming out to the surface by cracks and closed internal fractures by pores. From energy considerations, it is clear that the concentration of nanopores in a unit volume is much greater than the proportion of

micropores with radii of 10^{-6} m. This means that coal having micro-nanopores from 10^{11} units to 10^{20} units in one cubic centimeter of its volume concentrates huge tension and tremendous energy for doing useful work.

Using the above formula we calculate the voltage values for pore radii of 10^{-6} , 10^{-7} , 10^{-8} , 10^{-9} m: $U_e(10^{-6})=1.44 \cdot 10^3$ V; $U_e(10^{-7})=1.44 \cdot 10^5$ V; $U_e(10^{-8})=1.44 \cdot 10^9$ V; $U_e(10^{-9})=1.44 \cdot 10^{11}$ V. These voltages have accelerating effects on the emission electrons pulled by the abovementioned electric field strength $E(C_2)$. The velocity of the emission electrons moving under the action of the voltage $U_e(r_s)$ is expressed by

the formula $U_e(r_s) = \sqrt{\frac{2e}{m_e} * U(r)}$, where $m_e=9.108 \cdot 10^{-31}$ kg is the electron mass. Its kinetic energy is

$T_e(r_s) = (1/2)m_e U_e^2(r_s)$. Using them, we calculate the velocity and kinetic energy of the emission electron at $r_s=10^{-6}$ and $r_s=10^{-7}$ m: $U_e(10^{-6})=1.875 \cdot 10^7$ m/s; $T_e(10^{-6})=1.442 \cdot 10^3$ eV; $U_e(10^{-7})=1.875 \cdot 10^8$ m/s; $T_e(10^{-7})=1,442 \cdot 10^5$ eV. These classical formulas cease to work for other values of the pore radius since quantum effects appear. This does not mean that our reasoning is not true for them. They are true, but you need to use the apparatus of quantum physics and quantum chemistry. Since it is enough for us to show general effects that integrally express the entire electromagnetic picture of the process we remain within the framework of classical physics and chemistry [19, 22].

We emphasize that all chemical processes including chemical reactions are the essence of the electromagnetic interactions of atoms, an atom with a molecule, and a molecule with molecules. The gravitational interaction is 10^{42} times less than the electromagnetic interaction at the atomic-molecular level, and there are neither strong nor weak interactions. In other words, electromagnetism is the only interaction in obtaining nanopowders [19].

The emission electrons with kinetic energies $T_e(10^{-6}) \approx 10^3$ eV and $T_e(10^{-7}) \approx 10^5$ eV are used in X-ray equipment and γ -flaw detection of substances to form a stream of X-rays and γ -particles having a length and wave frequency: $\lambda(10^{-6})=1.241 \cdot 10^{-11}$ m; $\nu(10^{-6}) = 2.418 \cdot 10^{19}$ Hz; $\lambda(10^{-7})= 1.241 \cdot 10^{-13}$ m; $\nu(10^{-7})=2.418 \cdot 10^{21}$ Hz [17, 23]. Length and frequency of the scattering wave from an electron known from the experiment Compton: $\lambda_e=2,426 \cdot 10^{-12}$ m; $\nu_e=1.236 \cdot 10^{20}$ Hz can be easily obtained by standard arguments: $E_e=mc^2=8,186 \cdot 10^{-14}$ J= $h\nu_e$ or $\nu_e=E_e/h$, where $h=6.625 \cdot 10^{-34}$ J s is the Planck's constant and $c=2.998 \cdot 10^8$ m/s is the speed of the photon. Hence, $\nu_e=1.236 \cdot 10^{20}$ Hz and we obtain $\lambda_e=2,426 \cdot 10^{-12}$ m from the formula $c=\lambda_e \nu_e$. Considering that the Compton effect as the elastic scattering of X-rays and γ -rays by free or weakly bound electrons is accompanied by an increase in the length of the indicated rays [23] we can conclude a complete agreement of the process we described and the known experimental facts. This demonstrates the validity of our reasoning and indicates the source of energy that contributes to the technological process and its energy efficiency. Freshly formed surfaces are in a nonequilibrium state characterized by surface charge density (bare electrons). It is known from the experiments that their concentration is about 10^5 CGSE/cm². Recalculating it for the number of electrons with charge in the pendants we have $\kappa_e \sim 10^{14}$ e/cm². This is the experimentally determined number of electrons per each square centimetre of the surface of the discontinuities in solids.

Consider the issue of surface charge density in micro-nanopores. The surface area of individual pores is characterized by values on the order of 10^{-18} m² to 10^{-12} m². Above, we indicated the reference value of the bond length of the carbon molecule $L(C_2) \sim 0.771 \cdot 10^{-10}$ m. Therefore, in a spherical layer with a diameter of $4.626 \cdot 10^{-10}$ m (three diameters of C_2) cut from a sphere of radius $r_s \sim (10^{-9} \div 10^{-6})$ m there can be one molecule of C_2 . Such a segment has a surface area of the order of 10^{-18} m². Then, there can be located maximum $(10^{-18} \div 10^{-12}) \cdot 10^{-18} \text{ m}^2 / 10^{-18} \text{ m}^2$ between one and 10^6 segments on one surface of the pores. Since the area of 1 cm² accommodates κ units of single pores with radii $r_s \sim (10^{-9} \div 10^{-6})$ m their number will be: $\kappa = 1 \text{ cm}^2 / (10^{-18} \div 10^{-12}) \text{ m}^2 = (10^{14} \div 10^8)$ units. Then the maximum concentration or surface charge density is $10^{14} \times 1$ or $10^8 \times 10^6$ on 1 cm², i.e. $\kappa = 10^{14}$ e/cm². In other words, the experimentally determined κ_e and its calculated value κ have the same order. The coincidences of the theoretical and experimental values of the main characteristics of the electric field of a carbon molecule located on the surface of nano-micropores such as tension, voltage, surface charge density prove the adequacy of the constructed model of coal rocks and the formation of fresh pores in them as a result of reactor abrasion. Particles of hard rocks (silicon, iron, and titanium) play a special role in the attrition of coal to powder.

Maxwell-Lorentz electrodynamics [17] brings together magnetism and electricity. This is a consequence of Ampere's hypothesis of molecular current which states that a moving electric charge creates a

magnetic field. There are different opinions about this hypothesis, from full approval to categorical refusal. Nikola Tesla considers it erroneous [24], and in our opinion the Ampere hypothesis does not correspond to reality if only there is no magnetic field in superconductivity. In other words, the flow of electrical charges **without resistance**, i.e. there is a current without a magnetic field [22]. This means that the magnetic field is created by the flow of electric charges (electrons) which experience resistance from collisions with electrons and release the smallest magnetic particles from their depths and form a circular magnetic field around the conductor. Similarly, X-rays and γ -rays are generated by braking a flux of electrons on a metal plate with a kinetic energy of 10^3 eV and 10^5 eV respectively. It is known that these rays have great penetrating power and great intensity, but do not create an electric field. In other words, in either case, the manifestation of these particles is the same and indicates their **magnetic nature**. It follows that electrons are carriers not only of electric charges (unipolar particles), but also of bipolar magnetic particles.

We emphasize the validity of Nikola Tesla's ingenious conjecture [24] that “*speaking of electric charges, one must abandon the idea of two positive and negative charges*”. Tesla states that there is neither positive nor negative charge, but there is a charge without any signs and there is its elementary carrier in terms of indivisibility and indestructibility. Similarly, there is an elementary **bipolar magnetic particle**. It is formed by an electron. This is indicated by the decay of a neutron into a proton, an electron, and neutrino particles out of which the electron is not contained in the interior of the neutron (they have different sizes). Consequently, it is formed according to a special genetic program mainly from particles ejected from the depths of the neutron.

Thus, there are an electric particle and a magnetic particle. Each of them is an independently existing particle carrying only one type of entity, electricity or a magnet respectively. They are not reduced to each other being independent entities. The lack of understanding of this point can be explained by the absence of the law of interaction of magnetic particles on coal rocks and the experimental results on these effects. Therefore, let us return to the calculations of the characteristics of the magnetic fields of a carbon molecule and its atom. Let us recall that the intensity **H** of the magnetic field determines the magnetic induction **B** and the magnetic pressure: $B = \mu_0 H$, $P = (\mu_0/2)H^2$, where $\mu_0 = 4\pi \cdot 10^{-7}$ H/m is the magnetic constant. A vacuum of 3.610^{-2} N/m² and $3.6 \cdot 10^{-6}$ N/m² is created inside the micropores with radii of 10^{-7} m and 10^{-6} m. Consequently, the magnetic tension of the magnetic field lines breaks the bonds of electrons with the nucleus. This is a very important electron emission mechanism. The Langmuir frequency [23] of a $\omega_L = (4\pi e^2 \rho_e / m_e)^{1/2}$ of the electron with a concentration of 10^{14} e/cm² is equal to $2 \cdot 10^3$ Hz, its speed is equal to 10^7 m/s and therefore a shock wave arises [23]. This wave has a compression and expansion phase. The latter superimposed on the magnetic tension causes a significant destructive effect. Such secondary effects undoubtedly have a role and become an element of a single mechanism of abrasion of the rock in nanopowders along with the mechanochemical effects of Rehbinder [25].

Let us consider the matter of acoustic waves accompanying the listed physical effects, external waves from a sound generator. Note the speed *v* in m/s of longitudinal waves in rods of silicon is equal to (3700 ÷ 4900); aluminum – 5080; iron – 5170 and carbon – 2100. The intensity and pressure of sound waves determined by the relations $I_i = (\rho_i v_{ai}/2) \cdot (v_{oi})^2$ and $P_i = \rho_i v_{ai} v_{oi}$ are measured in (W/cm²) and (N/m²) [22]. In these formulas *i* refers to a substance (silicon, aluminum, iron, carbon), ρ_i is their density (kg/m³), v_{ai} is the speed of sound waves (indicated above) and v_{oi} is the oscillatory velocity of particles of a substance under the wave action. Even if v_{oi} is the same for all substances, then substances with different densities and velocities v_{ai} will experience different pressures from sound waves. Substances with a higher speed of wave propagation become concentrators of sound stress and relieve these over voltages freeing themselves from the environment. In other words, their bonds with carbon are broken and they are separated from coal rocks. The orientation of carbon molecules plays a significant role with respect to the direction of wave propagation. Molecules having transverse arrangements to the direction of the wave undergo a breaking of bonds. The internal and external (superimposed) magnetic fields play an important role in their reorientation. Since carbon is a diamagnetic, it always assumes a position with the orientation of the magnetic field in the direction opposite to the direction of the vector of the external field strength. Thus, the combined actions of vacuum, external and internal electric and magnetic fields, as well as external and internal sound fields, together with the dynamics of rock movement in the reactor under the influence of a rotating electromagnetic field produce a technological process of abrasion of coal rocks and

the production of nanopowders from them. Purification of nanopowders and their separation into fractions can be done in a different way. In particular, metals can be extracted by magnetic separation since all metals including non-magnetic aluminum and titanium are magnetized in a strong magnetic field, they can be removed by a strong electromagnet. There are effective methods of hydroflotation; special heavy flotation liquids have been developed for cleaning coal from ash. Finally, there is a method for aerodynamic separation of substances according to specific gravities, so that fractional separation of powder and the production of powders of individual elements are technologically feasible and quite effective with greater purity.

The process produces a sufficiently pure carbon powder and separate fractions of powders of oxides of silicon, aluminum, iron, titanium, potassium, calcium, manganese, and magnesium which require reduction. We refer to the known technologies for obtaining these substances in a reduced form [25, 32, 33].

Turning to low-carbon nanoenergy based on structured nanomaterials we will not consider photoenergy and other types of energy based on renewable energy sources (RES) including hydrogen and controlled thermonuclear energy. We will explore only the energy associated with coal and carbon. A large amount of liquid pyrolysis waste and a certain amount of coal dust are formed during the processing of highly coking coal to coke. Usually, one ton of coke, one ton of liquid pyrolysis waste and about one ton of hydrocarbon gases with coal dust are obtained when processing 3 tons of coal. These gases after cleaning are used for production needs, and coal dust is dumped [25, 32, 33]. Coal dust practically not having volatile combustible substances (gases) and being a hydrophilic substance is strongly moistened with atmospheric moisture. Therefore, it is poorly amenable to gasification and its direct use as an energy fuel. However, coal dust is a pure carbon material. Therefore, we obtained technical nanocarbon from the material having a wide industrial application at a low cost. The use of this nanocarbon in other sectors of the economy other than energetics will be considered specifically.

Liquid pyrolysis wastes called coke chemical (CCW) and stored in unqualified earthen barns create a formidable environmental problem. This is evident from the chemical composition of its liquid part which is about 60% of the mass, and the rest (about 40%) of the CCW is coal dust and coke. The CCW using the vacuum-wave hydroconversion technology is processed in a matrix of highly ionized water (plasma state) constituting 40% of mass of the CCW into liquid carbon fuel (LCF) with a low carbon content.

Let us give the chemical composition of the CCW obtained by the gas-liquid chromatographic mass spectrometry method (table 3).

From table 3, we can see the presence of a number of toxic compounds such as benzene, phenol, naphthalene, phenanthrene and others. The bulk of the liquid part of the CCW is made up of aromatic compounds with benzene rings of condensed and unfused nuclei which require high energy costs at break, straightening and hydrogenation. Such a technological process is carried out by the technological line of the vacuum-wave conversion of the CCW with the addition of highly ionized water (HIW) in the plasma state [26-31]. The HIW is introduced into the CCW in a nanodispersed state. It is in the form of exfoliated nano-inclusions and does not precipitate even during long-term storage (up to six months). HIW performs several functions: having a conductivity greater than carbon it electropolarizes the whole medium; having a higher dielectric constant than carbon it concentrates a huge amount of current line in its nano-droplets; when a certain critical number is exceeded these lines of currents mutually pushing away like parallel conductors break the nanodrops into hydrogen and hydroxide. In other words, HIW becomes a donor of hydrogen that participates during the life of its individual atoms and OH molecules for (10^{-12} – 10^{-10}) seconds in the process of intensive hydrogenation and saturation of carbon molecules with hydrogen by hydrogenation and the formation of primary monohydric alcohols from C_3 to C_{12} and up. These micro-explosion processes are even more intense when HIW drops have diameters of several tens of microns, and which has been found experimentally. Another fact has been established: coke and dust particles are activated and fully hydrogenated forming liquid carbon fuel with a high degree of hydrogenation. In fact, 40% of the HIW mass is assimilated as H and OH. This is an industrially implemented indicator of HIW digestibility by coke chemical waste. The obtained low-carbon fuel is certified as **hydrogenated energetic fuel TGE-40** (Russian trademark officially introduced in 2012).

It was possible to bring the proportion of HIW in the fuel to 72% of the mass under laboratory conditions, and its upper limit of 80% and higher was theoretically proved. This means the possibility of creating of low-carbon (less than 10% mass) nanoenergetics based on nanocarbon with the role of a

Table 3 – Chemical composition of CCW

No	Retention time, min	Peak area	Compound	%
1	5.4	758 799	Toluene	2.55
2	16.1	231 029	Phenol	0.78
3	16.3	51 569	Pyridine, 2,4,6-trimethyl-	0.17
4	17.6	111 497	Benzene, 1-ethynyl-4-methyl-	0.37
5	17.8	82 902	Phenol, 2-methyl-	0.28
6	18.2	263 311	Phenol, 4-methyl-	0.88
7	20.5	8 518 028	Naphthalene	28.59
8	21.8	469 919	Quinoline	1.58
9	22.2	1 482 402	Naphthalene, 2-methyl-	4.98
10	23.5	408 287	Biphenyl	1.37
11	23.7	128 100	Naphthalene, 1,6-dimethyl-	0.43
12	24.8	877 090	Biphenylene	2.94
13	25.2	618 351	Acenaphene	2.08
14	25.5	807 529	Dibenzofuran	2.71
15	26.5	1 586 800	Fluoren	5.33
16	26.7	96 772	9H-Xanthene	0.32
17	26.9	142 231	Dibenzofuran, 4-methyl-	0.48
18	27.0	65 071	1,1'-diphenyl, 2,2', 5.5' -tetramethyl-	0.22
19	28.8	80 278	Dibenzothiophene	0.27
20	29.2	3 624 895	Phenanthrene	12.17
21	29.3	939 011	Anthracene	3.15
22	30.1	279 543	Carbazole	0.94
23	30.2	249 992	Anthracene, 2-methyl-	0.84
24	30.7	271 220	4H-cyclopenta phenanthrene	0.91
25	32.3	2 662 912	Fluorantene	8.94
26	32.6	1 852 582	Pyrene	6.22
27	32.7	141 079	Benzo [b] naphtho [1,2-d] furan	0.47
28	33.7	99 888	7H-Benzo [c] fluorene	0.34
29	33.7	398 178	11H-Benzo [b] fluorene	1.34
30	35.7	108 593	Benzo [b] naphtho [1,2-d] thiophene	0.36
31	35.8	171 811	Cyclopenta [CD] pyrene	0.58
32	36.0	82 648	Naphtho (2,1-e) quinoline	0, 28
33	36.5	805 914	Benzo [a] anthracene	2.71
34	36.8	435 160	Triphenylene	1.46
35	37.1	98 931	Benzo (s) carbazole	0.33
36	42.6	788 828	Benzo [K] fluoranthene	2.65

catalyst and promoter of the production process of forming a fuel in a TGE. Nanocarbon is active during the first few months of life since its production, especially in the first few days. Therefore, it is desirable to combine the production process of LCF with the process of obtaining of nanocarbon integrating into a single technological chain.

Industrial and laboratory bench tests of TGE-40 showed its high calorific value [30, 31] with a calorific value of 12783 (kcal/kg) comparable to that of natural gas and greater by 25÷30% than that of heating fuel. Consequently, it completely replaces both natural gas and furnace fuel, and, moreover, furnace energy and ship fuel oil of petroleum origin. The environmental performance indicators of LCF are not inferior to natural gas and are significantly better than those of petroleum fuels including the maximum permissible concentrations (MPC) and emissions (MPE). Having an internal OH oxidant in alcohol compounds it has a lower consumption of atmospheric air and differs from natural gas in terms of emissions of nitric acid compounds for the better (lower by 30%). Due to the high content of hydrogen the temperature of combustion of LCF reaches up to 2300 and can provide long-flare combustion which is so necessary for many technological processes. Special videos were shot on burning LCF through nozzles, in drying ovens, boilers including energy boilers and on their use in diesel generators of electrical energy.

LCF has a kinematic viscosity of (8÷12) cSt (centistokes) at +20°C, a pour point below -27°C and a flash point above +60°C. These rheological indices allow transportation of fuel and air generators in road and rail tankers, by tanker and by pipeline. It is safer for transportation and storage than natural gas, less fire-explosive than the latter and does not contain mercaptans and hydrogen sulfide. In contrast to natural gas, LCF can be used in all types of stationary and mobile power plants, ships and ship gas turbine plants as gas turbine fuel.

The transition to the low-carbon nanoenergetics transforms coal into a wide resource base. It can be oriented to all kinds of industrial waste from plastic plants, acid tars, granary and other sludge, transformer, industrial, motor, hydraulic and other types of used oils. This could include spent rolling oils from steel and other steel mills. Their environmentally friendly recycling can be carried out by hydroconversion technology using carbon nanopowders, urban and industrial wastewater. Similarly, it would be possible to solve the problem of disposal of oil-contaminated water and soil.

Discussion of results. Strictly speaking nanotechnology as an applied direction of modern science is neither a supernatural nor a new miracle. Its essence lies in the discovery, recognition and use of the properties of matter, characteristic of its nano-sized components, as well as in the accumulation of new knowledge about matter, the interactions of its parts and on this basis reaching a higher level of cyclic, recycled waste of natural resources with its gradual decrease. Speaking about the properties of nanoparticles it is necessary to investigate the natural mechanisms of formation and renewal, for example, cells of living organisms or the formation of fossil energy carriers (oil, natural gas and coal).

Giving examples the organic compounds where the carbons between themselves and the atoms of other elements are chemically very strongly bound are involved in controlled and high-speed reactions in very harsh, energy-consuming conditions [25, 32, 33]. However, their measured, calm and steady state in a living cell disappears quickly under the action of enzymes (biological catalysts), and the biochemical reactions of their transformation are accelerated hundreds of millions and billions of times, as well as with mild conditions that do not threaten the functioning and life of organisms. The study of these biochemical processes has revealed patterns and their application in the sphere of tautomeric transformations of carbon in inanimate nature with speeds that are as many times as high as the above rates of biochemical processes. The tautomeric transformations of carbon which constitute a narrow area of their transformation under mild conditions (+ 25°C) are in progress with the breaking of old and the formation of new bonds in the form of a substitution reaction and the transfer of a group of atoms with dimensions of several decimal and hundredths of a nanometer. Another example is associated with chemically passive molecules of saturated hydrocarbons, but capable of activation and rapid reaction by the formation of coordination compounds with transition metals [25, 32, 33]. Nanopowders of the latter with sizes less than 10 nm ensure the flow of selective catalytic reactions with the synthesis of a wide range of organic compounds including methane under mild conditions and the lowest energy costs. Examples show the presence of a nanotechnological alternative to natural opportunities, and the results we have outlined are the presence of a nanotechnological alternative to resources, energy, and natural opportunities in general.

Citing examples of high technology in animate and inanimate nature we did not pursue the goal of opposing nanotechnology to other technologies, but only wanted to emphasize the need to take nature prompts into account. One of these clues is the high ash content of coal. The highest content in ash belongs to silicon oxide which has the highest chemical clark (16.35% in nature). Then comes alumina with the highest (4.99%) chemical clark among metals. It is known from chemistry that crystalline aluminosilicates called zeolites and formed from silicon and aluminum oxides are the most effective catalysts for the hydrogenation reaction of unsaturated hydrocarbon compounds, especially aromatic [32, 33]. At the same time, the active role belongs to the cations of alkali and alkaline-earth metals that are part of the zeolite. Considering the chemical composition of the ash we can see the participation of alkali metals in it; for example, sodium or potassium. Therefore, we can say that the sol played an active role in the formation of coal rocks where there was no access of oxygen and moisture from the outside and the internal moisture was used for hydrogenation processes of formation of volatile gases, mainly methane, and in an energy-efficient way to create aromatic hydrocarbons condensed and unfused benzene rings. Of course, in our case, zeolites could function as a catalyst and participate in the process of vacuum-wave conversion and hydroconversion of carbon and hydrocarbon compounds to final products that are close to equilibrium, even saturated and supersaturated hydrogen and OH compound. Since there is no sharp difference in the exact boundary between acid-base and redox reactions zeolites can also participate effectively in the reduction of silicon, aluminum, other metals and minerals from the composition of coal ash.

Thus, coal rocks contain natural zeolite catalysts that are necessary for hydrogenation and the production of low carbon liquid fuels. This opens up new opportunities in the formation of nanoindustry. We have developed a technological line for the production of pure and highly pure carbon nanopowders, oxides of silicon, aluminum, iron and titanium on the basis of the technology of dry conversion of coal rocks into nanopowders. Pure nanocarbon and silicon oxide are the main materials in the manufacturing of electrical insulation and rubber products. Pure nanocarbon can be used as an additive in a road bitumen to improve of an asphalt concretes strength [34, 35]. Silicon oxide in the recovery and purification gives technical grade silicon MG-Si which is produced from SoG-Si.

А. А. Қалыбай¹, Б. Б. Телтаев¹, А. К. Абжалиев²

¹Қазақстан жол ғылыми-зерттеу институты, Алматы, Қазақстан,

²Калгари Университеті, физика кафедрасы, Калгари, Канада

**НОНАЭНЕРГЕТИКАЛЫҚ МАТЕРИАЛДАР МЕН
ТӨМЕН КӨМІРТЕКТІ НАНОЭНЕРГЕТИКА:
ЗАҢДЫЛЫҚТАР, ТЕХНОЛОГИЯЛАР ЖӘНЕ ШИКІЗАТ**

Аннотация. Төмен сұрыпты көмір жыныстарының құрамына кіретін заттардан (көміртектен, металл тотығынан, тұздардан және минералдардан) алынатын энергиялық тиімді келесі материалдар өндірісінің физикалық, физика-химиялық және химиялық заңдылықтары ашылды, зерттелді және негізделді:

– наноэнергетикалық материалдар (нанокөміртек, кремнийдің, алюминийдің, титандың, темірдің, марганецтің, магнийдің және т.б. наноұнтақтары);

– төмен көміртекті сұйық жанармайдың, экологиялық таза, калориясы жоғары сапа параметрлері бойынша табиғи газбен салыстыруға болатын, бірақ, қауіпсіз, бағасы тарапынан арзан және газбен салыстырғанда тасымлдау және сақтау тарапынан ыңғайлы. Жыныстар тозуының, микрожарықшақтар және нанокеуектер нанобөлшектерінің өлшемдері наноэнергетикалық материалдар өндірісінің энергиялық тиімділігінің және төмен көміртекті наноэнергетиканы дамытудың сыни технологиялық параметрлері болып табылатыны анықталды.

Түйін сөздер: төмен сұрыпты көмір жынысы, күлділік, микрон-наноөлшемдердің жарықшақтары мен микрокеуектері, физикалық өріс, вакуум, сиретілудің соғылу толқындары, гидроконверсия, құрғақ конверсия, ішкі және сыртқы электр және магнит өрістерінің кернеулігі.

А. А. Калыбай¹, Б. Б. Телтаев¹, А. К. Абжалиев²

¹Казахстанский дорожный научно-исследовательский институт, Алматы, Казахстан,

²Университет Калгари, кафедра физики, Калгари, Канада

НАНОЭНЕРГЕТИЧЕСКИЕ МАТЕРИАЛЫ И НИЗКОУГЛЕРОДНАЯ НАНОЭНЕРГЕТИКА: ЗАКОНОМЕРНОСТИ, ТЕХНОЛОГИЯ И СЫРЬЕ

Аннотация. Открыты и изучены физические, физико-химические и химические закономерности и обоснована технология энергоэффективного производства из веществ (углерода, окиси металлов, солей и минералов), входящих в состав низкосортных угольных пород:

– наноэнергетических материалов (наноуглерод, нанопорошки кремния, алюминия, титана, железа, марганца, магния и т.д.);

– низкоуглеродного жидкого топлива, экологически чистого, высококалорийного сопоставимого по параметрам качества с природным газом, но безопасного, значительно дешевого по цене и удобного при транспортировке и хранении в сравнении с газом. Установлено что размеры наночастиц истирания, микро-трещин и нанопор пород являются критическими технологическими параметрами энергоэффективности производства наноэнергетических материалов и развития низкоуглеродной наноэнергетики.

Ключевые слова: угольная порода низкосортная, зольность, трещины и микропоры микрон-наноразмеров, физические поля, вакуум, ударные волны разряджения, гидроконверсия, сухая конверсия, напряженность внутренних и внешних электрических и магнитных полей.

Information about authors:

Kalybay Aisultan Abdulloovich, Kazakhstan Highway Research Institute, Almaty, Kazakhstan; ao_kazdornii@mail.ru; <https://orcid.org/0000-0002-7646-8991>

Teltayev Bagdat Burkhanbaiuly, Doctor of Technical Sciences, President of JSC “Kazakhstan Highway Research Institute”, JSC “KazdorNII”, Almaty, Kazakhstan; bagdatbt@yahoo.com;

Abzhaliyev Abulkhair Kairatovich, Master’s Degree Student, Department of Physics, University of Calgary, Calgary, Canada; abulkhair.abzhali@gmail.com; <https://orcid.org/0000-0003-2418-5014>

REFERENCES

- [1] Poul Ch., Owens F. Nanotechnology. Translation from English. M.: Technosphere, 2006. 336 p. (in Russ.).
- [2] Gusev A.I. Nanomaterials, nanostructures, nanotechnologies. M.: Fizmat lit., 2005. 416 p. (in Russ.).
- [3] Foster L. Nanotechnology. Science, innovation and opportunity. M.: URSS, 2008. 243 p. (in Russ.).
- [4] Minaev A.A. Monitoring of patent documents on nanotechnology // Patents and licenses. No. 12, 2010. 94 p. (in Russ.).
- [5] Nanotechnology in the coming decades. Forecast of research directions / Ed. Roko M.K., Williamsa R.S., Alivisatos P. M.: Mir, 2002. 292 p. (in Russ.).
- [6] Akyzbekova A., Absambetov M. Atlas of the energy potential of renewable energy sources of the Republic of Kazakhstan // Materials of the World Congress of Engineers and Scientists “Energy of the Future: Innovative Scenarios and Methods for Their Realization WSEC - 2017”. Astana, 2017. Vol. 2. P. 131-137 (in Russ.).
- [7] Bobylev S.N. Low carbon energy: new challenges for the raw material model of development // Materials of the World Congress of Engineers and Scientists “Energy of the Future: Innovative Scenarios and Methods for Their Realization WSEC - 2017”. Astana, 2017. Vol. 3. P. 120-124 (in Russ.).
- [8] Innovatsionnyu patent RK 11314. Innovative patent RK 11314. 2000. The method of conversion of hydrocarbons / Kalybaev A.A., Aspandiyarov B.B. (in Russ.).
- [9] AS Kalybay A.A., Aspandiyarov B.B. No. 28846. Wave generator, 2000 / 0785.1. 07/14/2000 (in Russ.).
- [10] AS Kalybay A.A., Aspandiyarov B.B. No. 28898. Device for wave processing of the medium, 2000 / 0786.1. 07/14/2000 (in Russ.).
- [11] Specifications TU 3689-001-38281705 - 2012 Technological line for vacuum-wave conversion of hydrocarbons by a magnetic-electric field in the fuel is light, medium and heavy distillate liquid (liquid fuel: for specific processing), gasoline AI-92, AI-95, AI-98 Euroclasses 4 and 5, diesel fuel Euroclasses 4 and 5, marine fuel and hydrogenated fuel of energy grade ТГЭ-40. M.: FBU "ROSTEST - MOSCOW", 2012. 26 p. (in Russ.).

- [12] Certificate of Conformity No. C-RU. AG98. B. 09607 - TP 1457858 Russian Federation: Oil Refining Equipment: technological line for the vacuum-wave conversion of hydrocarbon raw materials by a magneto-electric field and complies with the requirements of the Technical Regulations for the Safety of Machinery and Equipment (Government Decree of 15.09.2009 No. 753). 1 section (in Russ.).
- [13] Whitehurst DD, Mitchell TO, Farkashi M. Coal liquefaction. M.: Chemistry, 1986. 25 p. (in Russ.).
- [14] Alekseev A.D., Vasilenko T.A., Ulyanova E.B. The change in the volume of closed pores of fossil coal // Chem Solid Fuel 3. 1999. P. 39-45 (in Russ.).
- [15] Eremin I.V., Zharova M.N., Skripchenko G.B. The material composition, structure and properties of fossil coal in connection with their processing into liquid and gaseous fuels // Chem Solid Fuel 4. 1978. P. 22-29 (in Russ.).
- [16] Physical quantities. Reference book. Ed. Grigorieva I.S., Melikhova E.Z. M.: Energoizdat, 1991 (in Russ.).
- [17] Parsel E. Berkley Physics Course. Electricity and magnetism / Translation from English. M.: Science. The main editors of physical and mathematical literature, 1983. 416 p. (in Eng.).
- [18] Golosov S.M. Mechanical phenomena in superfine grinding. Novosibirsk: Science, Siberian Branch of the USSR Academy of Sciences, 1971. 216 p. (in Russ.).
- [19] Ivanov V.V., Poplavko E.M., Malevsky A.Yu. Mineral raw materials. Reference book. M.: ZAO Geoinformmark, 1998. 701 p. (in Russ.).
- [20] Kalybai A.A., Teltayev B.B., Abzhali A.K. Carbon and Nanoenergetic Materials // Symposium VIII. Almaty, 2018 (in Eng.).
- [21] State Register of Scientific Discoveries of the USSR from 1957 to 1987. Moscow: State Committee on Inventions and Discoveries at the State Committee on Science and Technology of the USSR, 1988. 160 p. (in Eng.).
- [22] Quick reference book of physical and chemical quantities / Editor K.P. Mishchenko. M.: Chemistry, 1974. 330 p. (Yavorsky B.M., Detlaf A.A. Physics Handbook. M.: Nauka, 1968. 612 p.) (in Russ.).
- [23] Ivanov B. The laws of physics. M.: Higher School, 1986. 335 p. (in Russ.).
- [24] Nikola Tesla. Lectures. Samara: Agni Publishing House, 2008. 312 p. (in Russ.).
- [25] Khrennikov T.M. Mechanochemical activation of coals. M.: Nedra, 1993. 176 p. (in Russ.).
- [26] Kalybai A.A. Energy efficient ultradeep hydroconversion of highly viscous hydrocarbons into motor fuels // Oil and gas. 2014. 1 (79). P. 45-59 (in Russ.).
- [27] Kalybai A.A., Nadirov N.K. New physical and chemical principles of deep processing of high-viscosity oils // Oil and gas. 2008. 3. P. 33-44 (in Russ.).
- [28] Kalybai A.A. Deep oil conversion by turbulent-wave molecular destruction // Oil and gas. 2003. 3. P. 72-79 (in Russ.).
- [29] Kalybai A.A. Theory and practice of cold cracking // Bulletin of the IA of Kazakhstan. 2003. 1(9). P. 78-81 (in Russ.).
- [30] Kalybai A.A. On the vacuum wave technology of deep processing of hydrocarbon raw materials // Oil and gas. 2008. 3. P. 80-89 (in Russ.).
- [31] Kalybai A.A., Zhumagulov B.T., Nadirov N.K., Abzhali A.K. Alternative technology for efficient processing of crude oil // Oil and gas. 2017. 3. P. 88-102 (in Russ.).
- [32] Krichko A.A., Lebedev V.V., Farberov I.L. Non-fuel use of coal. M.: Nedra, 1978. 214 p. (in Russ.).
- [33] Kucher R.V., Kompanets V.A., Butuzova L.F. The structure of fossil coal and their ability to oxidize. Kiev: Naukova Dumka, 1980. 167 p. (in Russ.).
- [34] Iskakbayev A.I., Teltayev B.B., Oliviero Rossi C., Estayev K. A new simple damage accumulation model for predicting of an asphalt concrete cyclic strength // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 5. P. 38-47. <https://doi.org/10.32014/2018.2518-170X.8>
- [35] Iskakbayev A.I., Teltayev B.B., Yensebayeva G.M., Kutimov K.S. Computer modeling of creep for hereditary materials by Abel's kernel // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. 2018. Vol. 6. P. 66-76. <https://doi.org/10.32014/2018.2518-170X.36>

**Publication Ethics and Publication Malpractice
in the journals of the National Academy of Sciences of the Republic of Kazakhstan**

For information on Ethics in publishing and Ethical guidelines for journal publication see <http://www.elsevier.com/publishingethics> and <http://www.elsevier.com/journal-authors/ethics>.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see <http://www.elsevier.com/postingpolicy>), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service <http://www.elsevier.com/editors/plagdetect>.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www.nauka-nanrk.kz

ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

<http://www.geolog-technical.kz/index.php/en/>

Верстка Д. Н. Калкабековой

Подписано в печать 11.06.2019.

Формат 70x881/8. Бумага офсетная. Печать – ризограф.
15,7 п.л. Тираж 300. Заказ 3.