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Research on development of nanotechnology in the Republic of Kazakhstan

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ABSTRACT

In the history of civilization, materials and technology that defined the face of the era have appeared more than once. It is enough to recall the "age" of bronze and iron, steam and electricity, the atomic "age" and the computer age. Nanomaterials (NM) are undoubtedly among such materials, and the 21st century opens the era of nanotechnology. Most experts in the field of science and technology policy, strategic planning and investment are confident that in the next decade nanorevolution is expected in all areas of science, production, defense, medicine, mode of life, recreation and entertainment. Its consequences will be more extensive than the consequences of the computer revolution in the last third of the 20th century, i.e., a large-scale and systematic invasion of nanostructured materials, products and methods of their production will literally come to all spheres of life. The paper analyzes the ways of nanotechnology development and the use of various nanomaterials and nanoproducts in various sectors of the world economy and environmental protection. Nanotechnology is a field of fundamental and applied science that provides theoretical justification for practical methods of research, production, and products application with an atomic structure by manipulating atoms and molecules. The aim of the work is to study the development of nanotechnology and its role in the modern economy. The article considers the ways of development of nanotechnology in Kazakhstan, as well as promising directions of their development and application in the field of mechanical engineering and industry in general.

Keywords: nanotechnology, nanomaterials, nanoscience, nanosystem technology, nanoproducts, nanomarket, nanotechnology development program, nanoproducts application, nanoindustry.

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Introduction

Manipulation at the atomic level enables to control features of new materials and nanomaterials. A material with measurement of one to 100 nm controls nanotechnology. Moreover, nanotechnology consists of showing, measuring, modeling and developing substanses in mentioned measurement range and they can been used in new ways [[1], [2]].

The main feature of nanomaterials to the nanosphere is that their size allows us to attribute objects in the nanoscale range from 1 to 100 nanometers by two or three dimensions. Except the main nanomaterials (nanofibers, nanotubes, and nanoparticles), there is a category of derived nanomaterials, which are complex structures formed from the main nanomaterials. Representatives of nanomaterial derivatives include nano-ceramics obtained by pressing and synthesizing initial nanoparticles, for instance, complex metal oxides. In this case, the composition of nanoceramics includes an amorphous (glassy) binder component as well as the crystalline nanoscale phase. Another example of nanomaterial derivatives are nanocomposites consisting of initial

nanoparticles, nanopipettes, nanophiles and (or) nanotubes interconnected by a polymer bond [[2], [3]].

This derivative provides nanomaterials by new useful properties such as increased strength, more elasticity, heat resistance, thermal and electrical conductivity, etc.

Experimental part

Worth to say, some previously known materials with nanoparticles were not considered as nanomaterials. Academician Tretyakov Yu.D. stated that faience, decorated with colored glaze to give ceramics a special shinea, was the first nanoparticle. The technology of creating a nanoproduct like faience was used by Umbrian potters in Italy in the 15th century. At that time, the reflectivity of nanoparticles (gold, silver and other metals) was used to give the faience an appropriate glitter of gold, silver, etc. Porcelain, created in China during Qin dynasty, is also a nanostructure, however, only in 1980-s when a scanning tunneling microscope was invented it became possible to distinguish nanostructures, that is, the necessary tool base appeared [[4], [5]].

With the development of nanotechnology, a number of new concepts have emerged in science: nanomaterials, nanosystem technique, nanotechnology, nanoappliances and nanoindustry. In the nanoindustry, markets of various directions are being formed and developed as nanocomplexes: nanoproducts (sale of licenses, certificates and industrial models); nanotechnology; nanoproducts; nanostructures and devices for monitoring nanoparticles.

Any of these markets is a “nanotechnological and economic paradigm” as a system representing a set of government bodies (at the macro level, supporting the development of nanotechnology and nanosciences), intersectoral regional scientific and production centers (at the level conducting research and development of nanoproducts), organizations and individuals interacting in order to realize their interests, nano projects and plans, scientific and technical and industrial programs (at the micro level, producing nanoroducts and having a targeted effect at micro-level). At the microlevel, nanoparticle producers (sellers) and buyers (legal entities – organizations and individuals) represent nanoparticle markets, each of them are trying to earn a commercial profit from sale-purchase transaction (Figure 1) [[5], [6]].

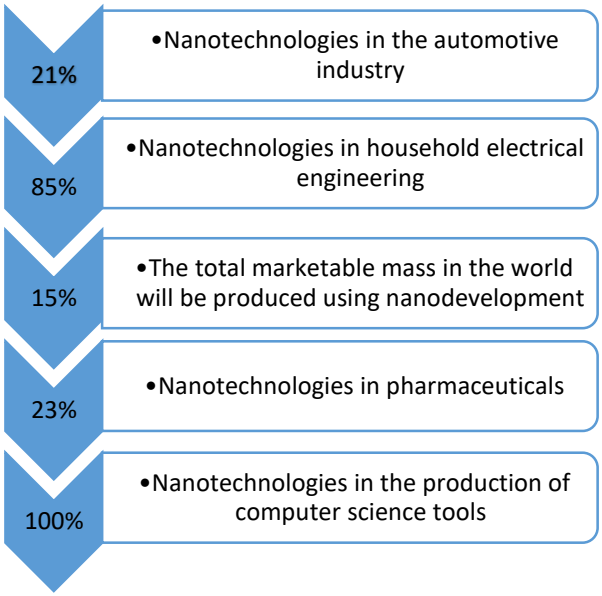

Figure 1 - The share of nanorevelopment in the commercial mass of industrial goods [5]

15% of the total marketable mass in the world will be produced using nanodevelopments. Today, there are more than 800 consumer products manufactured using nanotechnology on the world market – electronics, clothing, cosmetics, food, pharmaceuticals and household appliances [5].

The United States was the first to understand that nanotechnology is the near future of all mankind. Annual public and private investments in the US over the recent seven years amounted to about 2.5 billion US dollars. The state programs of americans for developing nanotechnology led to the leading positions in volumes of research in nanoindustry and output. The share of the United States (more than three thousand units in the sum of companies and individuals) accounts for about forty percent of patents in the field of nanotechnology obtained in all countries of the world [[6], [7], [8]].

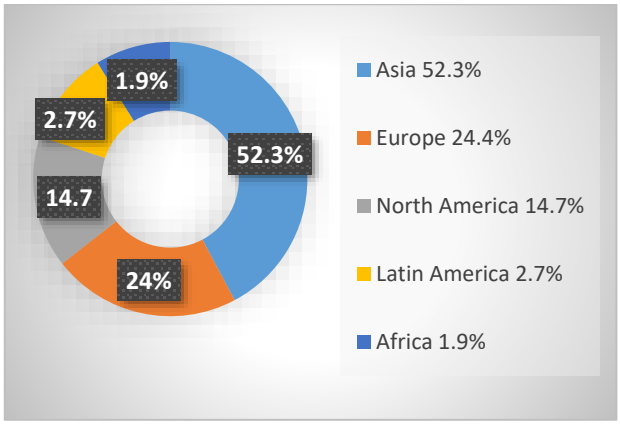

Figure 2 - Geographical distribution of publications on nanotechnology [9]

At the same time, according to the study, the largest number of scientific papers on nanotechnology falls on the countries of Asia and Oceania, more than half – on European countries and America, the smallest is on Africa (1.9%).

In the global nanoindustry, nanotechnology is used in the production of 600 types of primary nanomaterials and components and 80 groups of consumer goods.

Herein, 46% of the global nanoproducts and nanomaterials production is accounted for companies of the US nanoindustry, 28% of the nanoproducts production is accounted for European companies and 20% is accounted for East Asian countries (China, Japan, South Korea, and Taiwan). The rest of the world accounts for about 6% of the global production of nanomaterials and nanoproducts. The most popular material used in the production of nanoproducts are silver nanoparticles, using which about 320 types of nanomaterials and nanoproducts are produced. About 100 types of nanoproducts are produced using carbon nanoparticles (carbon nanotubes and nanopowders), 60 types using titanium dioxide and more than 40 types using silicon (Figure 2) [[9], [10], [11]].

The leaders of the rating are China, the United States, India, South Korea and Iran. At the same time, Russia took 12th, Belarus - 58th, Armenia - 81st, Uzbekistan - 86th, Georgia-89th, Tajikistan - 93rd, Kyrgyzstan-98th, Turkmenistan - 101st places. At the same time, according to the study, the largest number of scientific papers on nanotechnology falls on the countries of Asia and Oceania, more than half – on European countries and America, the less on Africa (1,9%) [11]

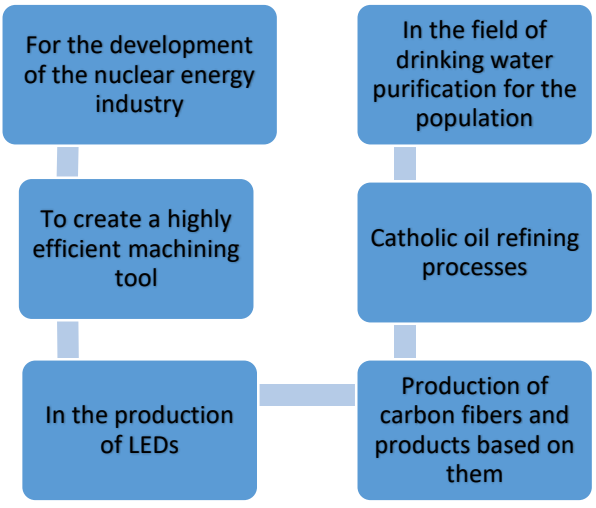

Figure 3 - Analysis of promising areas of nanotechnology use [14]

The importance of nanotechnologies [12] presents a specific research work in the field of nanoscale building materials carried out by the Federal Institute for Materials Research and Testing in Berlin.

Nanotechnologies create incredibly useful structures from individual atoms or molecules, the study [13] discusses the latest innovations in the field of oral health, nanocorporated products, patient safety and occupational safety.

The issues of using the historical penetration of nanotechnologies as a contribution to a reliable assessment of technological capabilities and a critical assessment of technological manifestations are considered (Figure 3) [14].

Research results and discussion

The analysis shows that there are research teams in Kazakhstan that carry out research and development in the field of nanotechnology and related disciplines. Nevertheless, the implementation of the program titled "Development of nanoscience and nanotechnology in the Republic of Kazakhstan for 2007-2009" showed that the country lacks a developed infrastructure that ensures the production of the necessary clean primary materials, the disposal of harmful waste, etc. All this hinders the development of fundamental and applied research, as well as the creation of nanomaterials and nanotechnologies, small innovative companies designed to become the driving force of the country's innovative development strategy.

Research centers that contribute to scientific and technical research in the field of nanotechnology are: Nazarbayev University, National Laboratory, National Nanotechnology Laboratory on the basis of KazNU named after al-Farabi, laboratory of the Institute of Physics and Technology, laboratory of engineering profile at TarSU, SKSU n.a. M. Dulati, SKSU n.a. M. Auezov, KazNU named after al-Farabi, Satpayev university, JSC “NSMC”, EKSTU n.a. D. Serikbayev, as well as the National Scientific Laboratory at East Kazakhstan State University n.a. S. Amanzholov. A significant contribution to the solution of scientific and technical problems in the field of nanotechnology was made by Nazarbayev University, national laboratories, in particular, the National Nanotechnology Laboratory on the basis of al-Farabi Kazakh National University, the laboratory of the Institute of Physics and Technology, the laboratory

of engineering profile at TarSU, SKSU n.a. M. Dulati, SKSU n.a. M. Auezov, KazNU named after al-Farabi, Satpayev university, JSC “NSMC”, EKSTU n.a. D. Serikbayev, as well as the National Scientific Laboratory at East Kazakhstan State University n.a. S. Amanzholov.

National Scientific Laboratory for Collective Use at the EKSU named after Sarsen Amanzholov was set up on October 8, 2009. The laboratory is equipped with a modern avance-III 500 nuclear magnetic resonance spectrometer manufactured by Bruker (Germany), X-ray diffractometers, electronic and optical microscopes, a vacuum station and other technological equipment that allows conducting studies of the structural and phase state and properties of materials. An experimental-industrial site has been created at the Laboratory.

A hydraulic press, 3D-draft and molding equipment for angular pressing of an equal channel were developed and manufactured with the support of the Foundation of the First President of the Republic of Kazakhstan. The mechanical properties of aluminum have significantly increased using them, namely, the hardness is 3 times, the yield strength is 18 times, the tensile strength is 5 times, the hardness of Titanium is 1.5 times.

The Laboratory of New Materials and Energy Saving Systems is known for its innovations, best practices and novelties, with a reputation as a world-class research institution that attracts the best students and employees not only in Kazakhstan, but also around the world. The laboratory closely cooperates with international researchers from leading world universities and research centers, such as the Tokyo Institute of Technology (Japan), the University of Warwick (Great Britain), Chungnam National University (Korea), Tokyo Metropolitan University (Japan), Sejong University (Korea), Tokyo University (Japan), Hanyang University (Korea), Hebei University of Technology (China), the French National Research Center (France), etc.

The National Laboratory for Nanotechnology "Nanofab" was established in 2008 at the South Kazakhstan State University (Shymkent city) to implement promising projects of nanotechnology and nanoindustry in order to implement state policy in the field of nanotechnology, create and develop innovative infrastructure in the field of nanotechnology, form the sector of Kazakhstani researchers in the nanoindustry as a whole. To conduct research and development work in the laboratory, it is planned to create conditions for the world's leading scientists and the possibility of training highly qualified domestic specialists. The laboratory plans to develop breakthrough projects in the field of nanotechnology based on the raw materials of Kazakhstan.

The laboratory is equipped with a scanning electron microscope of the Japanese company JEOL, as well as a system of energy-dispersion microanalysis and structural analysis of polycrystalline objects manufactured in the UK. Such a complex allows us to study the fine structure of organic and inorganic substances at the nanoscale.

The activity of the laboratory of engineering profile in the mining metallurgical and oil and gas sectors at KazNTU n.a. K. I. Satpayev is aimed at strengthening the material and technical base of the university, as well as at training highly qualified engineering personnel and developing innovative technologies in the field of earth sciences, metallurgy, mechanical engineering, oil and gas, ecology, bio- and nanomaterials, information systems [15].

“IRGETAS” Regional University Laboratory of engineering profile at the East Kazakhstan University is in the direction of “high technology for obtaining new materials based on the integrated use of resources of the mining and metallurgical industry.” It conducts research on natural nanomaterials, technologies for obtaining natural carbon nanoparticles, nanotechnology for opening ores of non-ferrous and precious metals, nanotechnology for obtaining nanofilms and nanowires, technical ceramics based on rare metal compounds, etc.

The laboratory of engineering profile "nanoengineering research methods" was established at Taraz State University to create a new generation of food products with high nutritional value based on the use of nanostructured food materials; to develop a technology for producing nanofiber from carbon-containing gas raw materials of the Amangeldy deposit; to conduct a complex of studies on improving the technology for obtaining composite materials on the basis of industrial waste; on the development of nano-and biotechnologies for obtaining new materials for the production of textile and light industry products based on vegetable and cellulose fibers; on the development of nanostructured coatings for natural and artificial leather with high performance property.

However, the development of nanotechnology in Kazakhstan also has weaknesses, in particular:

- there is no tradition of creating and developing nanotechnology;
- there is no coordination center for the implementation of state policy in the field of nanotechnology, the development of innovative

infrastructure in the field of nanotechnology, the implementation of projects to create promising nanotechnology and nanoindustry;

- insufficient funding of research and development projects in the field of nanotechnology;
- lack of long-term scientific and technical programs; Laboratories are practically not provided with modern technological equipment for the production of nanomaterials;
- lack of qualified personnel to support the industry; there are no permanent large-scale nanotechnology forums and world-class conferences;
- low level of information support on nanotechnology issues, lack of information in the state language;
- there is no unified terminology on nanotechnologies and nanomaterials that regulates the regulatory and methodological framework for conducting measurements, tests and control, establishing criteria for compliance, quality and safety of nanoobjects, nanomaterials and other nanotechnological products;
- low share of production of high-tech and knowledge-intensive types of products.

The main reason for the problems of technology development is the neglect of humanity to the core of its civilization – science – over the past few decades.

Fundamental science is a civilizational resource accumulated by past generations, wasted for profit. Kazakhstan now needs an innovative breakthrough in the nanotechnology of new plants, workshops and factories for the production of high-tech products based on domestic developments [[16], [17], [18]].

For the development of nanotechnology in Kazakhstan, the scientific side is being developed and the necessary specialists are being trained.

In mechanical engineering, there is an opportunity to increase the resource of metal cutting and processing tools using special coatings and emulsions due to the widespread introduction of nanotechnological developments and nanomaterials both in the modernization of the existing fleet of high-precision and precise machines, and in the production of new nanotechnological equipment.

Conclusions

Nowadays, there is a rapid growth of the market for consumption products based on nanotechnology. For example, the size of the global electronics and IT market using nanotechnology is more than $ 0.5 billion in 2010. Up to $ 1.8 billion by 2015, that is, more than three times. At that time, enterprises should be ready to develop high-tech products, otherwise new technologies may be sold abroad and not bring the necessary income to the country. As practice shows, many Russian enterprises cannot create competitive products based on high technologies.

As for nanomaterials, their fields of application and sales markets are growing very rapidly. The forecast for 10-12 years is that their volume will amount to more than 350 billion US dollars. The total volume of sales of nanoproducts per year is $ 1000 billion. Currently, nanomaterials are used in various spheres of human life, in the near future the scope of their application will significantly expand.

Kazakhstan's science is only taking the first steps in the field of production and use of nanomaterials and nanotechnologies, so in the future we can expect positive results from it.

Conflict of interests. On behalf of all authors, the correspondent author declares that there is no conflict of interests.

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Қазақстан Республикасындағы нанотехнологияның дамуын зерттеу

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ТҮЙІНДЕМЕ

Өркениеттің қазіргі тарихында дәуірдің келбетін анықтаған материалдар мен технологиялар бірнеше рет пайда болды. Қола мен темірдің, бу мен электрдің "ғасырын", атом "ғасырын" және компьютер ғасырын еске түсіру жеткілікті. Наноматериалдар (НМ) сөзсіз осындай материалдардың қатарына жатады және 21 ғасыр нанотехнология дәуірін ашады. Ғылыми-техникалық саясат, стратегиялық жоспарлау және инвестициялар саласындағы сарапшылардың көпшілігі алдағы онжылдықта нанореволюцияның ғылым, өндіріс, қорғаныс, медицина, өмір, демалыс және ойын-сауықтың барлық салаларында күтілетініне сенімді. Оның салдары XX ғасырдың соңғы үшінші бөлігіндегі компьютерлік революцияның салдарларынан да үлкен болады, яғни наноқұрылымды материалдар, бұйымдар мен оларды өндіру әдістері өмірдің барлық салаларына кең ауқымды және жүйелі түрде басып кіреді. Мақалада нанотехнологияны дамыту және әлемдік экономика мен қоршаған ортаны қорғаудың әртүрлі салаларында әртүрлі наноматериалдар мен наноөнімдерді пайдалану жолдары талданады. Нанотехнология – бұл атомдар мен молекулаларды басқару арқылы атом құрылымы бар өнімдерді зерттеудің, өндірудің және қолданудың практикалық әдістерін теориялық негіздеуді қамтамасыз ететін іргелі және қолданбалы ғылымның саласы. Жұмыстың мақсаты – нанотехнологияның дамуын және олардың қазіргі экономикадағы маңыздылығын зерттеу. Мақалада Қазақстандағы нанотехнологияларды дамыту жолдары, сондай-ақ оларды дамыту мен машина жасау және жалпы өнеркәсіп саласында қолданудың болашақтағы бағыттары қарастырылады.

Түйін сөздер: нанотехнологиялар, наноматериалдар, наноғылым, наножүйелік техника, наноөнімдер, нанонарығы, нанотехнологияны дамыту бағдарламасы, наноөнімдерді қолдану, наноиндустрия.

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Исследование развития нанотехнологий в Республике Казахстан

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АННОТАЦИЯ

В современной истории цивилизации материалы и технологии, определившие облик эпохи, появлялись не раз. Достаточно вспомнить "век" бронзы и железа, пара и электричества, атомный «век» и компьютерный век. Наноматериалы (НМ), несомненно, относятся к числу таких материалов, и 21 век открывает эру нанотехнологий. Большинство экспертов в области научно-технической политики, стратегического планирования и инвестиций уверены, что в ближайшее десятилетие нанореволюция ожидается во всех сферах науки, производства, обороны, медицины, быта, отдыха и развлечений. Ее последствия будут более масштабными, чем последствия компьютерной революции последней трети XX века, то есть масштабное и систематическое вторжение наноструктурированных материалов, изделий и методов их производства придет буквально во все сферы жизни. В статье анализируются пути развития нанотехнологий и использования различных наноматериалов и нанопродуктов в различных отраслях мировой экономики и охраны окружающей среды. Нанотехнология – это область фундаментальной и прикладной науки, обеспечивающая теоретическое обоснование практических методов исследования, производства и применения продуктов с атомной структурой путем манипулирования атомами и молекулами. Целью работы является изучение развития нанотехнологий и их значения в современной экономике. В статье рассматриваются пути развития нанотехнологий в Казахстане, а также перспективные направления их развития и применения в области машиностроения и промышленности в целом.

	Ключевые слова: нанотехнологии, наноматериалы, нанонаука, наносистемная техника, нанопродукты, нанорынок, программа развития нанотехнологий, применение нанопродуктов, наноиндустрия.
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