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ANALYSIS AND SYSTEMATIZATION OF MARKETING STUDIES DATA OF THE UKRAINIAN NANOPOWDER MARKET AND FORMATION OF THE PROGRAM FOR ITS DEVELOPMENT

Об'єктом дослідження є український ринок нанопорошків. Наявні літературні дані неповністю характеризують цю тематику. Їх систематизація дозволить вирішити дану проблему. Тому у роботі систематизовано літературні дані щодо розвитку української галузі нанотехнологій, зроблено прогноз терміну виходу окремих наноматеріалів на ринок. Також проаналізовано напрямки наукових досліджень і конструкторських робіт у цій галузі, зроблено вартісну оцінку виробництва наноматеріалів.

Проведений у роботі аналіз літературних джерел дозволив визначити започаткування та виконання цільових програм у галузі наноструктурних матеріалів і нанотехнологій в усіх провідних країнах світу. Наведено показники і тенденції розвитку сучасної української галузі нанотехнологій. Український ринок нанотехнологій знаходиться на початковому етапі свого становлення. У загальному обсязі інвестицій у нанотехнологічні проекти переважає державне фінансування. Сьогодні Україна значно відстає від розвинених країн за обсягом приватних інвестицій у дослідження в галузі нанотехнологій. Комерційний ринок нанопорошків в Україні практично не розвинений. В країні лише розпочинається впровадження стандартів нанопродукції та сертифікації діяльності підприємств. Дослідження українських компаній у галузі нанотехнологій спрямовано на модифікацію різних матеріалів. Запропоновано терміни виходу нанопорошків на комерційний ринок за галузями споживання. Наведено розподіл українських підприємств за галузями досліджень у сфері нанотехнологій та структуру проектів за галузями досліджень у сфері нанотехнологій. Проведено вартісний аналіз українського ринку нанопорошків. Визначено, що високу їх вартість обумовлює як низький обсяг виробництва, так і висока вартість вихідної сировини. Наведено основні галузі-споживачі нанопродукції в Україні та зроблено прогнози розвитку ринку до 2025 року.

Завдяки проведеному аналізу та систематизації літературних даних науковців щодо українського ринку нанопорошків та розгляду програм його розвитку забезпечується можливість отримання об'єктивної інформації стосовно українського ринку нанопорошків та прогнозування його подальшого розвитку.

Ключові слова: *прогноз розвитку українського ринку нанопорошків, маркетингове дослідження, фактори ціноутворення, галузі споживання.*

1. Introduction

The nanopowder industry is the most developed commercial sector of the nanomaterials market. The average annual increase is 15 % [1]. Achievements in the development and manufacture of nanostructures are mainly determined by the level of technology development. Such technologies make it possible to obtain nanostructures of the required configuration and dimension, as well as methods for complex diagnostics of the properties of nanostructures, including control in the production process and control of technological processes on its basis. According to many forecasts, it is the development of nanotechnology that will determine the progress of the 21st century, just as the discovery of atomic energy, the invention of a laser and a transistor, etc. identified the progress and development of the 20st century.

Important scientific and technical advances based on the analysis and control of processes at the level of atoms and molecules – at the nanolevel, are carried out in laboratories around the world. For example, the ability to control the synthesis of materials at the nanoscale level already now leads to the creation of new nanomaterials with new properties. The novelty of nanomaterials lies in the fact that with a decrease in the size of structural elements, they acquire fundamentally new properties. In the long term, nanotechnologies will gain even more revolutionary advances, with possible effects on virtually all industries, including energy, health care, defense, transport, electronics, etc. [2, 3]. Therefore, marketing research of the Ukrainian nanopowder market is an urgent task for the development of the nanotechnology industry.

2. The object of research and its technological audit

The object of research is the Ukrainian nanopowder market. In Ukraine, as in other countries of the world, nanoparticles of metals, alloys, oxides, oxygen-free ceramics are produced. The most common oxide nanopowders in Ukrainian industry are oxides of silicon, titanium, aluminum, iron, zirconium and copper. Among metal nanoparticles,

copper, iron, titanium, gold, platinum, and silicon have the greatest application [4, 5]. Methods for obtaining nanopowders are systematized and considered in [6, 7]. Available data on the scope of nanopowders of metals and their oxides in Ukraine require further analysis and systematization.

One of the most problematic places is the insufficient number of literary sources devoted to the object of research, not always their availability and unreliability.

3. The aim and objectives of research

The aim of research is a comprehensive analysis of the Ukrainian market of nanopowders and the formation of a forecast of its development.

To achieve this aim it is necessary to perform the following objectives:

1. Systematize the literature data on the characteristics of the modern Ukrainian region of nanotechnology by the most important indicators and development trends.

2. Make a forecast on the time of release of nanomaterials on the Ukrainian market.

3. Summarize the main directions of research and design work in this area and to analyze the distribution of enterprises by branches of research in the field of nanotechnology.

4. On the basis of the system analysis of the Ukrainian market of nanopowders to make their valuation and determine the industry-consumers of nanoproducts in Ukraine.

4. Research of existing solutions of the problem

All developed countries of the world have announced the start of implementation of targeted programs in the field of nanostructured materials and nanotechnologies. These programs are aimed at the further development of new technology, medicine, biology, ecology, etc. The end of the twentieth century was marked by the beginning of the nanotechnological revolution [8]. One of such areas of the socio-economic activity of society is the production of nanopowders [9, 10]. One of the attempts of modern classification of materials and methods of nanotechnology is the study [4]. There are already certain achievements, but the question of marketing research of the market of nanopowders remains unresolved for further development [11, 12]. The general characteristics of metallic and non-metallic nanopowders, the areas of their application are given in [13, 14].

The paper used the experience of marketing research in the industry, presented in [15, 16].

The current level of scientific research in the field of nanomaterials and nanotechnologies, planning of state programs and measures for their implementation in the countries of the world are given in [17, 18]. Consideration of the concepts of development of nanoindustry and the formation of the immediate prospects of this industry are devoted to the work [19, 20]. And the economic aspects of the development of the industry (business and pricing) are considered in [21, 22]. But the data on the planning and implementation of state programs for the concepts of development and the economic aspects of the nanoindustry require further systematization.

Electrochemical nanotechnologies are developed in Ukraine, in particular, the electrodeposition of nanostructured coatings and nanopowders by the electrolysis of ionic melts. The first direction includes coatings of molybdenum and tungsten carbides on grains of dispersed dielectric and semiconductor materials [23, 24]. In the second direction, nanopowders of carbides [25] and silicides [26, 27] of refractory metals are determined. Considerable attention is also paid to the technology of producing metal nanopowders [28, 29]. And also intermetallics [30, 31]. Electrochemical technologies are used to obtain nanopowders from spent tools [32, 33]. In order to return them to production, resource and energy savings are used nanopowders carbide materials and for the formation of composite electroplated coatings from aqueous electrolytes [34, 35] in order to restore machine parts. However, it should be noted that the above technologies are currently only at the laboratory and semi-industrial levels. In the future, the introduction of these technologies will contribute to the ability to control the crystal growth processes during electrodeposition [36, 37].

Nanotechnologies in Ukraine are used in the field of health and environmental protection [38]. In particular, this is the production of nanopowders of ferromagnetic biomedical and veterinary directions [39, 40]. Some progress has been made in this direction.

Also promising areas of application of nanopowders, both in Ukraine and abroad are:

– optics [41];
– automotive industry [42];
– electronics [43, 44];
– composite materials [45];
– agriculture [46].

Thus, the results of the analysis allow to conclude that the Ukrainian nanopowder market requires further study and systematization. To solve this problem, it is necessary to increase the level of knowledge on the nanotechnology industry in Ukraine [47, 48].

5. Methods of research

The following scientific methods are used:

– method of searching for literature data on the subject of modern development of nanotechnology and marketing research in this area;

– method of systematization and classification when conducting research on the achievements of modern science in the field of nanoindustry.

6. Research results

6.1. Ukrainian market of nanopowders

6.1.1. Review of the Ukrainian market of nanopowders. Modern Ukrainian nanotechnology industry is characterized by the following indicators and development trends [1, 49]:

– Ukrainian nanotechnology market is at the initial stage of its formation, at the stage of research and development (R&D) (in contrast to the leading countries with developed nanotechnologies, which have already begun to commercialize inventions). The share of Ukraine in the global technology sector is about 0.15 %, and in the nanotechnology market – 0.02 %. This lag is largely due to the fact that Ukraine began nanodevelopment 7–10 years later than other countries. Ukraine lags far behind the world nanotechnology leaders (USA, Japan and the EU) both in terms of R&D development and the degree of commercialization of inventions;

– in the total investment in nanotechnology projects, government funding dominates. The stages of development

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of the nanomarket in Ukraine are similar to those of the United States, Japan, and Germany. In these countries, at the initial stage of development, public investment in nanotechnologies also prevailed, which later became the impetus for attracting private investment in the nanobranch;

– today, Ukraine is significantly behind the developed countries in terms of private investment in nanotechnology research: their volume is up to 2–5 million USD in year. This is due both to the presence of high investment risks for economic entities and to an insignificant percentage of nanodevelopments brought to the start-up stage;

– commercial market in Ukraine is practically undeveloped: this is evidenced by the presence of rare projects implemented in production. Some companies have received prototypes of nanomaterials (nanotubes, fullerenes, etc.). On an industrial scale, nanotechnology products are practically not produced;

– among the main factors that have a positive effect on the Ukrainian market is state support for the sector, as well as a significant amount of public investment in the sector;

– in Ukraine, the introduction of standards for nanoproduction and certification of enterprises is just beginning; no statistics are available on the number of companies on the market. The number of businesses that use the term nano- for marketing purposes is also increasing. The available range of products on the Ukrainian market indicates that more than 95 % of them are not related to nanodevelopments;

– 90 % of the market is occupied by public or private-public companies; the private sector is represented to a lesser extent, which adversely affects the development of the commercial market;

– research of Ukrainian companies in the field of nanotechnology is aimed mainly at the modification of various materials: nanocomposites, nanotubes, fullerenes, nanoparticles, nanomembranes and the like.

According to the state of R&D in the field of nanomaterials development it is possible to envisage indicators for their time to market, as presented in Table 1.

Table 1

Time to nanomaterials entering the market

1–5 years	5–10 years	10–15 years	More than 15 years
Cosmetics	Chemical catalysts	Solar cells	Microprocessors
Textile	Paints	Compact power systems	Quantum computers
Coating	Medicinal materials	Biomaterials	Molecular processors
Lubricant	Medical diagnosis	Implants	Nanobiology, nanomedicine
Display	Nanomatrix	–	Nanoelectromechanics
Sensors	Product Packaging	–	Regeneration of tissues, organs
Composites	Energy, fuel, lighting	–	–

Note: systematized and summarized by the authors on the basis of literature data [4, 5]

6.1.2. The main R&D directions. Ukrainian research in the field of nanotechnology will rotate beyond 2000. Today, more than 100 scientific organizations are engaged in development in this area. Despite the active development of R&D with nanotechnology in Ukraine, the level of readiness of most projects is still very far from their commercial implementation.

As already noted, a significant part of projects in the field of nanotechnology in Ukraine is still at the R&D stage. This is indicated, in particular, by the distribution of requests for funding by type of project.

According to a survey conducted among nanocompanies, more than a third of them conduct research in the field of nanomaterials (Fig. 1).

If consider the R&D structure by industry, the most widespread is the introduction of nanotechnology in electronics, energy and medicine (Fig. 2).

Scientific development of technologies for the production of nanopowders, as well as practical aspects of their application, are carried out mainly in research institutes. One of the first attempts to study the Ukrainian market of nanopowders and nanotechnology business are works [1, 49].

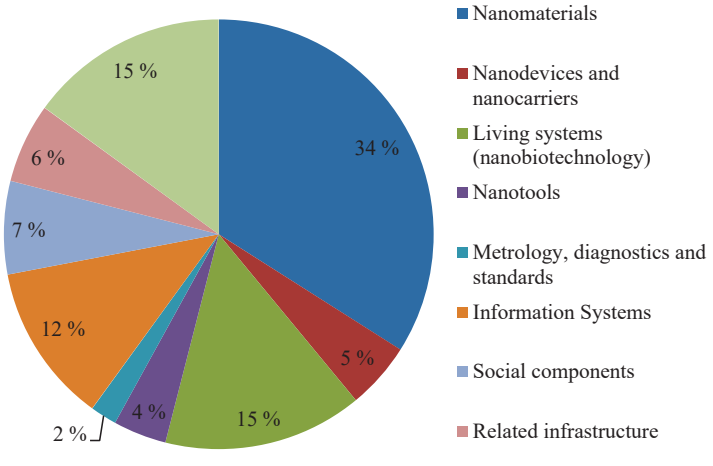

Fig. 1. Distribution of enterprises by branches of research in nanotechnology [5, 50]

In general, the following areas of research in the field of nanopowders are distinguished [49, 51]:

– metallurgy (steel quality improvement, development and production of nanoceramics, various functional materials);

– energy, in particular, nuclear (fuel cells, structural and thermal materials);

– medicine and pharmacology (drugs and drugs of general and local action, surgical and dental instruments);

– gas, mining and engineering industries (wear-resistant equipment, gas and oil pipelines, sensors, catalysts);

– security system (means of detection of harmful substances, collective and individual protection, life support).

Research in the field of nanopowders is at a rather higher level compared to other sectors of the Ukrainian nanoindustry. It is this type of nanomaterials gradually gaining market positions.

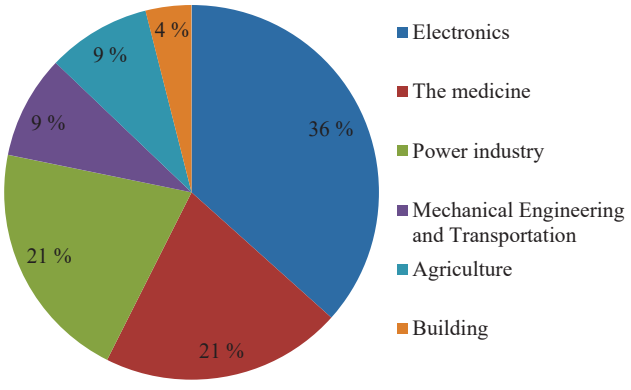

Fig. 2. Structure of projects by branches of research in nanotechnology [5, 50]

6.1.3. Characteristics of the Ukrainian market of nanopowders. Nanopowders belong to the group of materials, not a product of final consumption. They are used to produce various types of nanoproducts. Market participants note that today investors are showing interest in end-product types based on powders or in technologies for their use.

Production of nanopowders began in Ukraine in the middle of the 20th century. The long history of research in this field has led to the fact that today nanopowders and the technology for their production is one of the largest commercial segments of the nanoindustry in Ukraine. The practical use of nanopowders in various industries is negligible.

For commercial products manufactured using nanopowders, wear-resistant coatings, anti-wear products, ceramic products, composite materials, as well as medical products.

Today, the production of nanopowders in Ukraine is about 50 tons/year. Real production is much less. According to expert estimates, it is at the level of 5–10 tons/year. Taking into account the dynamic development of the global nanomaterials sector, Ukraine's share in the global market is extremely small, about 0.001 %.

A significant part of the nanopowders are manufactured by research parties for their own research purposes or by special order and only a small amount is sold on the market. The main producers of nanopowders are research institutes and universities. The demand for nanopowders in the domestic market is still quite limited, only a small number of enterprises use them in the manufacture of their products. Basically, nanopowders buy various scientific organizations to conduct their own research.

Both in the world and in Ukraine, the production of oxide nanopowders is the most developed. The second popular direction is the manufacture of nanodispersed diamonds.

Positive development in the market contributes to government support in the field of nanotechnology, as well as a significant amount of investment that comes from various government programs.

There is inertness, aversion of innovations and a limited amount of private investment by Ukrainian companies in conducting research inherent in Ukrainian business.

With the growing interest in nanotechnology in Ukraine, more and more companies are using the word «nano-» for marketing purposes. The potential volume of the Ukrainian market of nanopowders is estimated at 5–15 thousand tons/year:

– at the enterprises of electronics for use as condenser powders of metals – 5–10 tons/year;
– in the automotive industry for the manufacture of catalysts for the oxidation of monoxide carbon to up to 5 thousand tons/year;
– at the enterprises of the military complex for the manufacture of sensors – 50–250 kg/year.

In general, it is possible to assume that while maintaining the existing state and investment support of the nanotechnology sector, the nanomaterials market in Ukraine is able to develop at a significant pace compared with the world. Foreign trade in nanopowders is practically undeveloped. The volume of exported nanopowders in the total number of appointments is less than 0.1 %.

6.1.4. Market participants. Among Ukrainian enterprises operating in the market of powder materials and products from them is the Dniprospetsstal plant in Zaporizhzhia and the Kremenets powder metallurgy plant.

6.1.5. Cost analysis. Most Ukrainian manufacturers note only the estimated cost of nanopowders. Their cost includes many factors, among which the purity of the source material and the volume of the order are decisive. The cost of nanopowders and the size of its particles are determined. Thus, the cost of copper nanopowder with an average particle size of 70 nm is higher than with a size of 90 nm, almost 30 %.

The average cost of nanopowders of metal oxides on the Ukrainian market, USD/kg: zirconium oxide – 290, aluminum oxide – 125, barium titanate – 95, copper oxide – 90, iron oxide – 85.

The high cost of nanopowders is also characteristic of the world market, which is due to both low production and high cost of raw materials.

6.1.6. Industries-consumers in Ukraine. The main potential consumers of nanopowders in Ukraine are metallurgy, electronics, energy, medicine, engineering and the transport industry.

Metallurgy. The scope of the metallurgical industry is the creation of construction materials using nanopowders. The potential demand for nanopowders in this area is due to the fact that the reserves for increasing the mechanical characteristics of steels of various structural classes using alloying elements have been almost exhausted. The potential market of nanopowders is practically the entire metallurgical industry. In 2015, 1.5 billion tons of steel were produced in the world, of which 80 million in Ukraine. In terms of replacing traditional doping with nanomodifiers, the size of the nanopowder market in this segment can reach 60 million.

At present, representatives of powerful industries, in particular, metallurgy, are engaged in investing in nanotechnology projects. Thus, Zaporizhstal, within the framework of its own program for the development of nanotechnologies, finances a project to study the effect of nanopowders of refractory compounds (nitrides, carbides, etc.) on improving the mechanical and performance properties of various structural steel grades. In the future it is planned to organize the production of our own products using nanotechnology.

Innovative research to improve the properties of aluminum is partially funded. One of the priorities is to reduce the cost per ton of products using a new «inert anode» technology. The specificity of these developments is the use of nanomaterials and, in particular, nickel nanopowders, in inert anodes of the $NiFe_2O_4$–Fe_2O_3–Ni system. This has

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increased the strength of aluminum. The introduction of nanopowders to the electrolyte during galvanic deposition of the anode coating leads to a multiple increase in the corrosion resistance of the anode.

Preventions of the large-scale introduction of nanopowders in the metallurgical industry are as follows:

– decrease in the production of metal products due to the economic crisis, which led to a decrease in effective demand and deterioration of the situation in the domestic and world markets;
– price barriers – to increase the use of nanopowders, it is necessary to ensure their economic competitiveness;
– conservatism of the metallurgical industry, the rejection of innovation.

Electronics. The Ukrainian industry of electronic products lags behind Europe, North America and South Asia in terms of technology. The main restraining factor in the industry is the unpreparedness of Ukrainian producers to compete with imported products in terms of price/quality ratio, inability to operate in a market economy, and the low efficiency of public-private partnerships.

Energy. In the energy sector, the potential demand for nanopowders is in the field of alternative, in particular, solar and hydrogen energy. Thus, for the production of solar cells it is possible to use titanium dioxide nanopowders, as one of the most promising nanomaterials. This made it possible to reduce the cost of production compared with analogues based on silicon semiconductors.

Another area of application of nanopowders in the energy sector is hydrogen energy and the production of fuel cells. The most promising is the use of palladium nanopowders. Research in the field of hydrogen energy in Ukraine is carried out by research organizations. Much attention is paid to the production of fuel cells for cars.

Due to the fact that the market for alternative energy in Ukraine is practically undeveloped, the potential of using nanopowders is very limited.

Mechanical engineering. The use of nanopowders in engineering can lead to a significant economic effect. The EU estimates that 1 EUR spent on coating for cutting tools can save 5 EUR.

The Ukrainian engineering industry is characterized by the following negative indicators:

– low level of technological development;
– low competitiveness in the world;
– products are manufactured according to standards that do not meet international requirements and have a low level of unification;
– equipment does not meet technical requirements.

Low perception in engineering, in particular, Ukrainian, innovation limits the formation of demand for nanopowders. One of the promising areas of application of nanopowders in this area is the creation of nanodiamond cutting tools for the construction industry. By the end of 2017 in Ukraine it is planned to master the industrial production of diamond cutting tools, which is able to provide at least 20 % of the annual needs of the country's construction complex, as well as the export of products. In particular, the replacement of traditional powders of nanopowders in the coatings of the working surfaces of the piston group of internal combustion engines reduces the burn-in time and significantly (by 12–15 %) reduces the coefficient of friction.

The medicine. The fields of medicine and cosmetology are among the largest consumers of nanopowders in the world. Ukraine also conducts research on the use of nanopowders in health care, in particular:

– in oncology (nanopowders of iron, platinum metals, cerium, etc.);
– in surgery (nanopowders of silver, iron, etc.);
– for the production of biocidal materials;
– in bioprosthetics;
– for genetic diagnosis of diseases using test systems.

Transport. Nanopowders are used in the aerospace industry and aircraft industry. Their use allows to increase, in particular, the strength and corrosion resistance of structural materials. An important development of nanoindustry is ceramic nanocement (or phosphate ceramics), which can be used in the production of high-strength sleepers for high-speed railways, reinforced concrete structures of bridges and power lines, tunnels, laying retaining walls, to fill cadastral voids in the form of a gel, and the like.

6.2. Market development forecasts

All types of nanopowders are divided into groups depending on their prospects and the predicted dynamics of development. The most promising are complex oxides (antimony-tin, indium-tin), as well as zinc oxide used in electronics. In addition, this group includes silica, alumina, titanium oxide, titanium nanopowders, iron, barium titanate, nanodiamonds, silicon nitride, neodymium oxides, europium, dysprosium, and the like. Also in demand are powders of oxides of iron, zirconium, cerium, yttrium, magnesium, and also pure metals: nickel, zinc, silver, gold, aluminum, tungsten, platinum, molybdenum, silicon. Copper-based compounds in particular are in the least demand, since a sharp rise in prices for raw materials leads consumers to look for alternative materials and technologies [52, 53].

If today nanopowders are used mainly in the manufacturing industry, construction materials, electronics and many other industries, then in 2020 their applications are likely to shift towards environmental programs, and in subsequent years in medicine and biology (in particular, improving targeted drug delivery).

Forecasts of nanopowder production until 2025 are given in Table 2. Increased demand for nanopowders will help to increase their production and, as a result, reduce their cost.

Table 2

Nanopowder production forecasts (t/year)

Products	2010–2015	2015–2020	2020–2025
Nickel nanopowder	3500	7500	15000
Yttrium oxide nanopowder	2500	7000	7500
Cerium oxide nanopowder	–	10000	–
Silicon dioxide nanopowder	100000	100000	More than 100000
Titanium dioxide nanopowder	5000	5000	More than 10000
Zinc oxide nanopowder	20	–	–

Note: systematized and summarized by the authors on the basis of literature data [4, 5]

However, even optimistic market forecasts indicate that nanopowders will be produced in smaller quantities than similar traditional materials. So, according to expert estimates, in 2020–2025 about 100,000 tons of nanopowders will be produced in the world. This is due to the fact that the main characteristic of nanoparticles will not be their volume, but physicochemical and medico-biological characteristics.

It is possible that in Ukraine the production of nanopowders will gradually conquer the market of their traditional counterparts. It should also be borne in mind that the large-scale introduction of nanopowders into production will be hampered by the fact that their use does not always lead to an improvement in properties.

As expected, the main consumers will be the space industry, aircraft manufacturing, the automotive industry, as well as the production of consumer goods. The closest to commercial implementation are projects using nanopowders in consumer products – nanostructured coatings, products in the field of electronics, the production of catalysts in biology and medicine, and the like.

7. SWOT analysis of research results

Strengths. The latest literary sources on the subject of marketing research of the Ukrainian market of nanopowders are used in the work. The combination of data on technology and marketing research allows to more fully disclose the topic. Conducted research allows to determine the prospects for the development of nanotechnology for individual types of products.

Weaknesses. Underdevelopment of the Ukrainian nanotechnology market at the present stage of development.

Opportunities. Further research will be focused on using the results of the analysis of the Ukrainian nanopowder market conducted in the work for the further forecasting of its development. Advances in nanotechnology are the result of the implementation of the state program for the development of nanotechnology. Therefore, previous experience will allow a more reasonable approach to the formation of the following measures for the development of the industry.

Threats. The turbulent changes in the areas of nanotechnology research and their introduction into production are sometimes far ahead of planned activities and indicators.

8. Conclusions

1. Systematization of literature data on the characteristics of modern Ukrainian nanotechnology by the most important indicators and development trends shows that the Ukrainian nanotechnology market is at the initial stage of its formation. The total amount of investment in nanotechnology projects is dominated by government funding. Today, Ukraine lags far behind developed countries in terms of private investment and the commercial market in the country is practically undeveloped.

2. From the forecast made for the release of nanomaterials to the Ukrainian market, it can be seen that the introduction of nanomaterials and nanotechnologies for the production of chemical catalysts, paints and varnishes, medicines, composites for the energy, fuel and metallurgical industries is expected in the near future.

3. A generalization of the main areas of research and development work in the field of nanotechnology shows that the main enterprises:

– in the fields of research is the production of nanomaterials, their use in nanodevices and living systems (nanobiotechnology) and nanotools;

– in the fields of research – electronics, the medicine, energy, engineering and transport.

Scientific development of technologies for producing nanopowders, mainly carried out in the fields of metallurgy, energy, medicine and pharmacology, fuel and energy enterprises.

4. The system analysis of the Ukrainian nanopowder market shows that the high cost of nanopowders on the Ukrainian market is due to the low production volume and the high cost of raw materials and equipment. It is also determined that the main potential consumers of nanopowders in Ukraine in the near future are metallurgy, energy, electronics, medicine, engineering and the transport industry.

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