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DEVELOPMENT OF NEW SUBSTANCES AND MATERIALS IN THE WORLD AND IN UKRAINE[1]

The article includes the results of the analysis in the field of new substances and materials in the world and particularly in Ukraine. The author says that there are a lot of definitions of the term "advanced materials", and there are some points of view what advanced materials are and how it influences the economic development. Author highlights that the sphere of researching in the field of advanced materials and substances is actual and it is in the focus of the scientific community. Author has analyzed what countries are leaders in this direction and why they got their positions. The most important idea in the article is how low-income countries can take part in this direction of scientific researches. Ukraine is one of the examples which show how a low-income country can develop its own research in the field of advanced materials and substances. In addition the author has researched European Union's experience in innovation policy and innovation sphere particularly in the field of advanced materials.

Keywords: new substances and materials, innovation policy, innovation in low-income countries, implementation of innovation, innovation and competition.

Problem statement. The theme of advanced materials (and substances) is quite wide. There are many aspects of it, and at the same time this theme is quite new and important. It is well known that research in this field is one of the most important directions in modern science. New materials are the factor which makes most strongly influences on the innovation in the industry and scientific progress. That's why this theme is in the focus of the article.

Analysis of recent publications and unsolved parts of general problem. A lot of scientists work in this field, so this theme is well researched. But from the standpoint of economic sphere of advanced materials is poorly explored. It is well known, that the rich countries (such as the USA) make a major contribution to the research of this theme. But the role of low-income countries is little known, and that's why this role is interesting to researchers.

The purpose of article is to show what Ukrainian research in the sphere of new substances and materials means in world context, and what types of new materials are the most perspective in that moment.

Main results of the research. Using of terminology and methodology is quite important in researching in the field of advanced materials. The question is that scientists in Ukraine use different terminology than scientists in European countries. There is also a different point of view to this problem in the Ukraine scientific community [1].

In most countries scientists use term "advanced materials" to indentify some materials, which have been discovered or designed recently, and which have new and useful qualities.

[1] Публікацію підготовлено за виконання НДР «Імплементація високих технологій в економіку України», державний реєстраційний номер № 0112 U004938

In the same time Ukrainian scientists in those cases use term “new substances and materials”.

We believe that the term “advanced materials” is much more correct. Although the State Statistic service of Ukraine proposes their review with terms such as “new substances and materials”, we apply the term “advanced materials”. There are many definitions of the term “advanced materials” in special literature, but we sustain the next one: as “advanced materials” we talk about those, which are new ones for science, and which have new qualities. Advanced materials could be used instead of traditional ones. For instance, in the future new types of ceramic and composite will replace steel and aluminum [2].

There are such qualities of materials as hardness, strength, elasticity, etc. But it is more important, that advanced materials can have totally new qualities. For example, superconductivity, infusibility. These materials can have different origin. They can be composite materials, polymeric materials, nanomaterials.

We should say that advanced materials are quite popular in scientific society as directions of research. It is obvious that the direction of developing new materials for industry has been an important aim for scientists. And researches in the field of advanced materials have been enough intensive for last few decades. It is difficult question to choose the method how to measure the intensity of scientific researches. There are few of them, but we use only two – quotation rate and the number of patents. The method of quotation rate is not versatile and it has a few disadvantages. But in general it shows the intensity and effectiveness of research. Moreover, this method can show the results for some countries, universities, labs and researchers. We used Thomson Reuters’s database. According to the Thomson Reuters’s base, 655,718 scientific articles were been published on the topic “advanced materials” during the period of 1995-2013 years [4].

In USA, during the same period (1995-2013 years), 937216 patents were redistricted. A number of articles, which had been published in this field, increase each year. 30 mil articles were published in the period of 1995-1997 years, and 90 mil articles were published in the period of 2007-2009 years. For that reason we can say about high interest to that theme from the side of scientific community, because there is not such dynamics in other fields of research. We should say in addition, that main parts of all numbers of these articles are results of practice researches. In the Table 1 there are data about numbers of articles in the field of advanced materials and their topics.

Table 1 – **Numbers of scientific articles (which had been published in Thomson Reuters’ journal) and numbers of patents in the sphere of advanced materials; the structure of their subjects (during 1995-2013 years)**

(developed by author on the basis of [4; 7] and numerous empirical data)

Theme of patents	Amount of patents	Theme of scientific articles	Amount of articles
Composite and hybrid materials	219775	Materials based on silicon	139111
Polymers	189532	Metals and alloys	102315
Materials based on membrane properties	184304	Ceramic materials	102077
Coverings (with new features)	174054	Materials based on membrane properties	101527
Metals and alloys	147727	Composite and hybrid materials	99814
Materials based on silicon	124658	Coverings (with new features)	92680
Smart materials	102330	Smart materials	90458
Ceramic materials	67348	NDT technologies	33288

As we can see, there is a great difference in quantity of articles between different areas of research. Moreover, there is strong connection between number of patents and articles. Namely, some directions of researches could be presented by numerous articles, but in the same time they could not have significant number of patents.

It is possible to explain the fact that some areas of researches have many applicant studies, and as a result they present a lot of patents. But some areas of researches have theoretical character, and their main results are articles. When we say about the most practical and important areas of researches, we mean studies in the areas of composite materials, polymers and new types of cowering.

In the Table 2 there are data about the amount of articles in the field of advanced materials and their dynamic.

Table 2 – **Dynamic of the amount of scientific articles (which had been published in Thomson Reuters' journal) and amount of patents in the sphere of advanced materials; the structure of their subjects (during 2006-2011 years)**

(developed by author on the basis of [4; 7] and numerous empirical data)

Theme of patents	Dynamic (+/-), %	Theme of scientific articles	Dynamic (+/-), %
Composite and hybrid materials	+13%	Materials based on silicon	+3%
Polymers	+12%	Metals and alloys	+8%
Materials based on membrane properties	+9%	Ceramic materials	+4%
Coverings (with new features)	+5%	Materials based on membrane properties	+8%
Metals and alloys	+11%	Composite and hybrid materials	+7%
Materials based on silicon	0%	Coverings (with new features)	+6%
Smart materials	+3%	Smart materials	+7%
Ceramic materials	+11%	–	–

As we can see in Table 2, there are much more patents than articles in the field of advanced materials. There is a difference among directions of researches. Some of them show maximum increase (in the field of composite materials it is 13%), but some have not got increase at all. Perhaps a large number of patents and fewer articles mean that there is not such strong interest in theoretical research. As we can see by the results in Table 3, there is difference in the resultativity of individual countries. Of course, if we consider as effectiveness the publications and citation rates.

If we talk about the countries that are leaders in this market, it is necessary to point out the leadership of the USA and some of the richest countries. First of all, these countries are Japan, Germany and other EU members. At the same time some countries are demonstrate rapid growth (such as China, Republic of Korea). But if considered as the main indicator of the quality of their articles and not the quantity (the level citations is the main indicator), the USA leadership is beyond suspicion.

It is most likely that in the future the United States will keep their leadership in the field of advanced technologies, although the gap between the United States and the other leading countries will be reduced. The impact of poor countries on scientific results will be minimal. As it is well known, at the moment in Asia such countries as China, Japan and Republic of Korea are leaders of scientific activity. It is a high chance that in the future this situation will continue. If we talk about the EU, the richest countries show the highest results of scientific activities. These countries are Germany, France and Britain. Small EU countries do not have a fundamental influence on the situation. We can affirm the same about their position in the world [1].

Table 3 – **Dynamic of the amount of scientific articles (which had been published in Thomson Reuters' journal) in the sphere of advanced materials in some countries (in 2013 year)** (developed by author on the basis of [4; 7] and numerous empirical data)

Country	Dynamic of activity, 2005-2010 years, %	Amount of articles	References	References of one article	GDP per one person, 2010, billion $USA
USA	-5%	247093	1420270	5,75	14,447,10
China	46%	156933	43523	0,28	5,930,53
Japan	3%	363910	744212	2,05	5,488,42
Germany	2%	59648	132409	2,22	3,258,95
France	5%	15474	27509	1,78	2,549,03
GB	3%	13235	44954	3,40	2,251,90
Brazil	11%	2006	936	0,47	2,143,04
Italy	3%	5785	13491	2,33	2,043,64
India	15%	1025	1594	1,56	1,684,32
Canada	3%	2780	8069	2,90	1,577,04
Russia	10%	2780	8069	2,90	1,577,04
Spain	12%	1801	1396	0,78	1,383,34
Ukraine	17%	214	179	0,84	136,42

As we can see from the Table 3, only developed countries can support research on advanced technologies and materials. Moreover, each country of them should have a strong network of research institutions, a large number of qualified scientists, developed scientific institutions. The country which did not have these conditions (for example, Saudi Arabia), did not show significant results, despite investing huge money. Table 4 presents the data publication activity in some countries and their GDP. As we can see, these indicators are not always dependent on each other. Thus, many countries with high GDP do not make a significant contribution to the science developing, in particular, they do not make a contribution to the advanced technology. At the same time, some countries that do not have high level of GDP, conducted research in this area and get meaningful results. These countries are Sweden and Poland, for example. That is, the effectiveness of scientific research in the country depends from now and then on the research and innovation sphere, and the maturity of scientific traditions and effective scientific institutions. The same one can be said about innovation. The experience of the EU members is the most revealing in the context of an effective policy in the field of advanced technologies and materials; as European development institutions demonstrate good results in support of innovation. In general, the problem of the development and implementation of advanced technologies and materials has two aspects. The first aspect of the advanced technology is that the set of industries require the use of advanced materials with special capabilities (especially durable materials, semiconductors, catalysts). In these special cases these materials are rare earth metals. But the problem is that the main supplier of these metals on the world market is China.

Table 4 – **Amount of articles in the field of advanced materials (which had been published in Thomson Reuters' journal) in countries, that have GDP about 200 billion $ (during period 1995-2011)**
(developed by author on the basis of [4, 7] and numerous empirical data)

Country	Amount of articles
Switzerland	10168
Poland	10363
Belgium	8151
Swiss	9459
Saudi Arabia	1711
Norway	2634
Venezuela	515
Austria	5131
Argentina	2567
SAR	1964
Thailand	1969
Denmark	3640
Greece	4676
Columbia	649

That is why the rare earth metals production carries a number of risks. At the moment there are only a few alternatives in using rare earth metals: production of waste and recycling of old equipment. In the future, the scope for innovative technologies and materials will be to find a replacement for rare earth metals. It is quite possible. Moreover, new materials and substances will be cheaper and more accessible. Another aspect of the development and production of new materials and substances is that competition between industrial plants is very high. Therefore, the requirements for construction materials are increasing. Rare earth metals in the near future will not meet the requirements of industry. There is no choice to develop new materials on an alternative basis because of this situation.

Therefore, the strategy of countries the members of the EU in this area is to develop and to implement technologies for recycling and recovery of rare earth metals that are used (in short term); to improve processing technology and to obtain the recovered materials with predetermined propertie (in the medium term); to develop and to implement new substances and materials (in the long term). These substances and materials in their physical properties will exceed all rare earth metals. Meanwhile it is officially noted that the scope of new substances and materials have been developing rapidly in the last time. This trend will continue in the future. As a result, the technological basis for production of leading industrial countries of the world will change radically in the future time. Supporting their research is the fundamental question of competition for these countries.

According to the above mentioned information innovation EU policy in the context of production mostly needs development of new substances and materials production areas such as: 1) new solar cells (i.e. of energy generation and climate change); 2) new batteries (i.e., of climate change and care for the environment); 3) solids as a source of light (i.e., of climate change and care for the environment); 4) gas turbines; 5) health care.

The most vivid demonstration of penetration of new substances in the production of materials traceability of these trends is the example of certain products. Table 5 shows an example from which materials of modern mobile phone are composed.

Table 5 – **Example how different types of materials can be used to make mobile phone** (developed by author on the basis of [6; 10] and numerous empirical data)

Type of materials	Share of each material in mobile phone
Iron alloy	27%
Copper alloys	11%
Magnesium alloys	3%
Other metals	2%
Glass and ceramics	8%
Thermoplastics	27%
Rubber	5%
Other organic materials	2%
Battery	15%

The emergence of a sustainable scientific and practical interest in new substances and materials has its own history. Probably the technology received the biggest push after the oil crisis of the 1970s. More known trend that then engulfed the sphere of production is energy efficiency [8], especially the efficiency of fuel combustion. Less known tendency of technology is the reducing the weight of different machines, generally cars. Obviously, the lighter the vehicle is, the less energy is required as a rule for its work. If before oil crisis this trend had been limited, after it became common.

Mostly such materials include aluminum and magnesium alloys, carbon, fiberglass reinforced, and the variety of composite materials [9]. Cost of production (permanently reduced) enables their wide spreading in other areas of production, but limits physical properties (strength, ability to withstand temperature), limits the technical applicability. Thus, the practice of these materials leads to further improvement. This direction is not only basic research. The nature of these materials can extend the potential of their application by modifying their structure (experiments with ratios of individual components, manufacturing process), development and production of new subtypes that are optimized for a particular specification.

History of construction materials manufacture for machines and tools is a good example of the process of replacing old materials (steel, aluminum) with new ones. At the time, aluminum completely replaced the iron in aviation industry. The same process occurred in the automotive industry. Aluminum and light alloys almost completely replaced the steel, modern cars have a small fraction of the iron. However, there were cases of emergence in industry of completely new materials. One such example is the emergence of composite materials. This new material generally had the same cost as traditional materials. But its quality was much better. Such a case happened with enclosures for cars. Recently enclosures for were cars made of steel. But now enclosures for cars are made of special plastic, or using so-called technology PET (polyethylene terephtalate).

Another way to new displacement "traditional" materials and new materials is increasing demand on the part of producers, consumers and the state to the environmental aspect of production, use and recycling of construction materials. Thus, a large number of known cases where the substance over a long period which was used in production, due to increasing demands on the part of third parties considered unfriendly towards the environment (or unfit for use and disposal). In this case, it is being replaced by other substances. These new substances are replacing traditional ones by friendlier to the environment and human health (and although new materials have the best physical properties). This process includes three directions. The first direction is the denying from the use of harmful metals such as chromium, lead, cadmium, bismuth. The second direction is the development of new types of covering and surface treatment technologies, which would avoid the dangers to health of traditional materials (such as aluminum surface treatment technology products). The third direction is the substitution of hazardous substances emergence of innovative structural materials. These new structural materials must have other physical and operational characteristics. However, these new quality should be based on the unique properties and characteristics of hybrid materials or for fundamentally new technologies. Examples of these new substances are substances that are produced with nanoscale fibers.

Distribution of new materials is the case when a new material starting used in the production because of the low price. Such cases occur frequently, and not only in high technologies and high-tech manufacturing. The numerous new technologies of storage and transportation of food products, new construction technologies and technologies operating housing are examples of fit.

The principle thing is that this area of research has considerable potential for technology transfer to intensive scientific cooperation, including international cooperation. In the future, every country that has a developed industry will have urgent need of new substances and materials. This issue is even more important for private companies.

There are recent examples where several large technology companies have come out of the market because of ignoring innovation. However, there is no country (except, perhaps, the United States) that will be able to support all research areas independently. Therefore, there is no alternative to common research projects and technology transfer. In this context Ukraine has good prospects. Ukraine, despite the long period of degradation of science, now occupies a significant position in some segments of the sphere of new substances and materials (in particular in the field of semiconductors, powder metallurgy) [3]. Ukrainian research institutions will participate in joint research projects and technology transfer as partners or contractors (despite the lack of necessary funds and absence of significant domestic demand for research results).

Conclusions and prospects for further research. This area of research is quite undeveloped, and there are a lot of directions, which are not well investigated. Moreover, this sphere is one of the most dynamic, and in the nearest future it will strongly influence the innovation activity as a whole.

So, this sphere is one of the most important as the factor of innovative development. There is high probability that in the future there will be several totally new materials, which can change production principles at all. For example, the use of semiconductors completely changed the principles of the electronics industry in that time. This area is important for every researcher in the sphere of economics, because as we say about some aspects of innovation activity, so we should mention about connection between the intensity of innovation activity and the results of scientific activity (the emergence of new innovative products needs new construction materials, with totally new physical properties).

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Розроблення нових речовин та матеріалів у світі та в Україні

У статті представлені дані про сучасний стан досліджень у сфері нових речовин і матеріалів. Розглянуто основні тенденції досліджень у цій сфері. Виявлені країни, дослідницькі установи яких займають провідні позиції в розробленні нових речовин і матеріалів. Здійснено аналіз економічного значення наукового прогресу в цій сфері, його вплив на інтенсивність інноваційної діяльності у цілому. Виявлено внесок країн із низьким рівнем доходу в цю сферу наукових досліджень.

Ключові слова: нові речовини і матеріали, інноваційна політика, інновації в країнах із низьким рівнем доходу, реалізація інновацій, інновація і конкуренція.

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Разработка новых веществ и материалов в мире и в Украине

В статье представлены данные о современном состоянии исследований в области новых веществ и материалов. Рассмотрены основные тенденции исследований этой сферы. Выявлены страны, исследовательские учреждения которых занимают ведущие позиции в разработке новых веществ и материалов. Осуществлен анализ экономического значения научного прогресса в этой сфере, его влияние на интенсивность инновационной деятельности в целом. Выявлен вклад стран с низким уровнем дохода в это направление научных исследований.

Ключевые слова: новые вещества и материалы, инновационная политика, инновации в странах с низким уровнем дохода, реализация инноваций, инновация и конкуренция.

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