World market for nanomaterials: structure and trends

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Abstract. Modern nanomaterials as well as the other advanced materials are aimed at scaled production application due to their unique physical and chemicals properties and the improved performance of final products, therefore at enforcing technological and economic progress of the countries. The article focuses on current state and key indicators of development of the world nanomaterials market, its key drivers and restraints, modern structure, emerging trends and prospects. Selected foreign and Russian databases, providing information on nanomaterials, which are applied in industrial production, and final products manufactured with the use of nanomaterials or nanotechnology are examined in the article. The authors come to the conclusion that information asymmetry, heterogeneity and even inconsistency of the information in the databases exist, thus making it difficult to obtain relevant business information both for manufacturers and consumers. These factors hinder development of nanoindustry in the Russian Federation, as well as national and regional markets for nano-enabled consumer products.

1 Dynamics and trends of the world nanomaterials market

The development and industrial application of innovative advanced materials is imperative for technological and economic progress of a country. Nanomaterials, with at least one external dimension in the size range of approximately 1 to 100 nanometers, due to their unique physical and chemicals properties resulting in improved performance and qualitative characteristics of final products and ample opportunities of applying in numerous end-user industries are widely used in energy storage, construction, electronics, aerospace, defense, production of sporting and other consumer goods, etc.

The modern drivers of the world nanomaterials market are as follows: increase in the market penetration of existing materials, decrease in the prices of nanomaterials, improving materials' properties, expending R&D activities related to the new materials, increase in public and private expenditure towards nanotechnology research, growing support of the government institutions, rapid new materials and applications' development [1-3], effective functioning the partnerships and strategic alliances of domestic and foreign companies and organizations, increasing number and collaboration among industry players including growing international research and production cooperation in nanotechnology industry.

The factors mentioned above have had a positive impact on the development of the world nanomaterials market and have resulted in the steady growth of the key market indicators. As to the conservative estimate by Mordor Intelligence, the global nanomaterials market was valued at about USD 4.1 billion in 2015 and expected to reach USD 11.3 billion by 2020, at a compound annual growth rate (CAGR) of over 22% during the forecast period 2017-2022 [4].

On the contrary, the new report by Allied Market Research optimistically projects the global nanomaterials market to reach more than USD 55.0 billion by 2022 from USD 14.7 billion in 2015, growing at a CAGR of 20.7% during this time period [5], while Deloitte Touche Tohmatsu Limited experts are much less optimistic declaring only 15.5% CAGR of global nanomaterials market in 2012-2019 [6, p. 4].

The pessimistic and optimistic views on the positive dynamics and prospects of the global value of nanomaterials have been presented at figures 1 [3, 4] and 2 [2, 5] below.

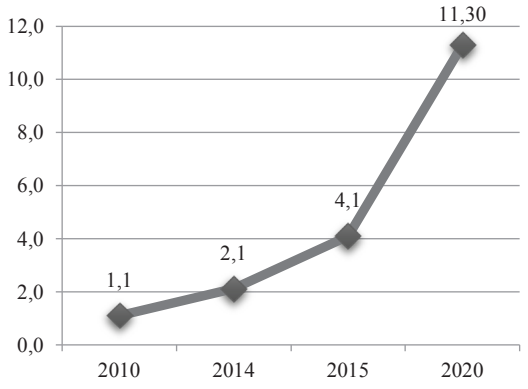

Fig. 1. Global value of nanomaterials, pessimistic view (USD billion).

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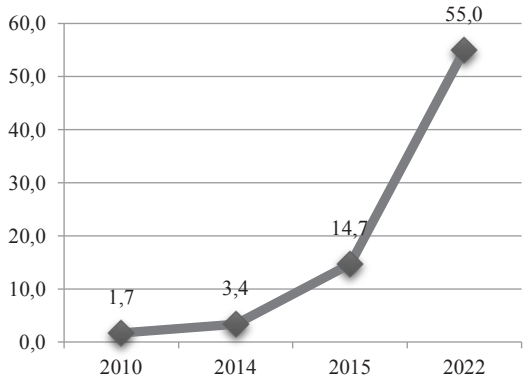

Fig. 2. Global value of nanomaterials, optimistic view (USD billion).

The European nanomaterials market generated revenue of more than USD 2.5 billion in 2015 and is expected to reach USD 9.1 billion by 2022 with a CAGR of 20.0% during 2016-2022 [7].

No matter what scenario of development of the global nanomaterials market has been taken into consideration, the fact is that it is expected to grow at a faster CAGR than the global nanotechnology market as a whole. The latter is projected by the RNCOS analysts to grow at a CAGR of around 17% during the forecasted period of 2017-2024 [8].

Major factors restraining development of the global nanomaterials market are: the growing concerns over their impact on human health and the environment (toxicity of nanomaterials themselves, presence of toxic solvents, release of hazardous intermediate compounds, toxicity of wastes resulted from nanomaterials' processing or manufacturing); stringent requirements in the frameworks of the government environmental regulation.

For example, the International Agency for Research on Cancer (IARC) states that oral exposure to titanium dioxide (known as E171 and presented in sweets, chocolate products, toothpaste, pharmaceutical products, etc.) becomes a factor of initiating and promoting early stages of colorectal carcinogenesis for humans.

The most important regulatory bodies related to nanomaterials in the US and the EU are:

– The United States Environmental Protection Agency (EPA), setting national standards of environmental protection and enforcing regulations in this sphere (The Toxic Substances Control Act, TSCA; Resource Conservation and Recovery Act, RCRA; etc.);

– The European Chemicals Agency (ECHA), facilitating the implementation of the obligations under the crucial regulations: Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH); the Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation); The Biocidal Product Regulation (BPR, Regulation (EU) 528/2012), and others.

In China, for example, it is the Ministry of Industry and Information Technology (MIIT), which has published new guidelines for industries that create new materials, such as graphene. The guidelines had been jointly developed by the MIIT, the National Development and Reform Commission, the Ministry of Science and Technology and the Ministry of Finance.

It should be mentioned the emerging trends in the global nanomaterials industry: growing demand for high strength and durable structural materials, new material development and product design, new and emerging market applications, falling nanomaterials' prices, enlarging the scale of the market due to the growing activities of the existing suppliers and the new entrants, as well as the increase in government support and R&D funding.

2 Structure of the world nanomaterials market by type of material, region and application

By material type, one can find several approaches to segmenting the global market for nanomaterials: a) carbon based, metal and non-metal oxides, metals, dendrimers, nanoclay, and nanocellulose [7]; b) nano-particles, nano-fibers, nano-tubes, nano-clays and nano-wires [4]; c) carbon black, carbon nanotubes, graphene, fullerene, nanofibers; silica fumes; clay; metal/alloys; ceramics [9]; and some others.

Allied Market Research experts team states that metal and non-metal oxide-based nanomaterials are the most widely applied in the industrial production with expected growth at a CAGR of 20.7% from 2016 to 2022 [5]. About 25% of the nanoproducts introduced into the markets are incorporated by titanium dioxide, silver, or silicon dioxide nanoparticles [14, p. 65] Titanium dioxide and silicon dioxide are mostly consumed metal and non-metal oxide-based nanomaterials. Consumption of silicon dioxide was 198 kilo tons in 2015 and is projected to reach 786 kilo ton by 2022, at a CAGR of 21.8%.

Nano silver due to its antibacterial and antimicrobial properties is among the most popular nanomaterials used in manufacturing consumer products by the companies in numerous industries, mostly electronics, IT, healthcare and beauty, textiles (20% of the world silver nanoparticles market).

Silver nanoparticles are considered by the Global Market Insights Inc. analysts to be the most commercialized nanoparticles, accounting for over 50% of the global nanomaterial consumer products in 2015 [10] with expectation of growth of the market at a CAGR of nearly 13% in 2016-2024 [11]. Prior areas of silver nanoparticles application are healthcare and life sciences, food and beverages packaging industry (improved packaging and active packaging), electronics and IT sector.

The global markets for nanoclay and nanocellulose also demonstrate stable growth of the indicators based on the enlarging spheres of their industrial application [5]. According to the Transparency Market Research (TMR) forecasts, the market revenue of nanoclay is expected to grow at a CAGR of 24.9%, and of nanocellulose market – 19% until at list 2020 [12, 13].

The prospects of selected nanomaterials markets have been summarized in the table 1.

Table 1. Selected nanomaterials markets.

Selected nanomaterials market	Global market revenue by 2016, USD billion	Expected global market revenue by 2021, USD billion	Expected CAGR in 2016-2021, percent
Silver nanoparticles	1.1	3.0	13
Nanoclays	0,7	2,1	24,9
Nanocomposites	1.6	5.3	26.7
Quantum dots	0.61	3.4	41.3
Nanofibers	0.39	2.0	38.6
Advanced & nanoscale ceramic powders	14.6	22.3	8.9

Source: Silver Nanoparticles Market Size (2017); Global Silver Nanoparticles Market Trends (2017); Nanocellulose Market (2015); Nanoclay market (2016); Nanomaterials Market – Global Opportunity Analysis (2016).

Dynamics of the global nanomaterials demand by regions and sectors can be seen at figure 3 [2, 5].

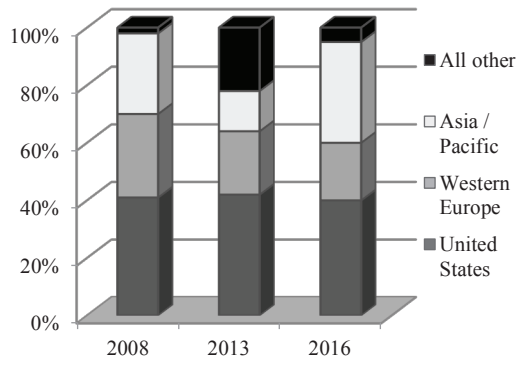

Fig. 3. Global demand for nanomaterials by regions (percentage).

In 2014, the US and Japan accounted for over a half of world demand for nanomaterials, while the EU countries and two high-income East-Asian countries, Taiwan and South Korea, represented an additional 34%.

The US led the global nanomaterials market in 2015 and is projected to keep this leading position until 2022 with the nanomaterials market revenue growing at a CAGR of 20.5%.

In 2016, North America and Asia-Pacific collectively accounted for 3/4 of the world demand for nanomaterials and are expected to maintain leadership throughout the examining period. At the same time, the highest CAGR of nanomaterials market revenues is projected in Asia-Pacific countries (21.4%), backed by North America and Europe.

Among the Asian countries the fastest growth in demand for nanomaterials is forecasted for China and India, while China is predicted to become the second largest market for nanomaterials following the U.S. with over 11% share of the global demand by 2022.

On the basis of applications, one should identify the following segments in the structure of the global nanomaterials market: electrical and electronics industry, construction, energy storage, healthcare, consumer goods, packaging, transportation, aerospace, water filtration, and others.

Nevertheless, the Allied Market Research analysts point out the industries with the highest opportunities for applying modern nanomaterials in production of the final goods: aerospace, sporting goods, automotive, energy storage, electronics and defence industries [7]. The electronics industry is expected to account for the highest share in the market (about 30%), while the aerospace sector - the fastest growing sector during the forecast period due to the increasing usage of nanometals, polymer nanocomposites and anti-corrosion coatings in the aircraft manufacturing.

3 Nanomaterials development and production: problems of representation in the databases

The development of applied research in the field of nanomaterials and nanotechnology can be represented by the positive dynamics of the patent activity of countries, that is by the growing number of patents issued by international and regional (see tables 2 and 3) registration systems.

The generalised information in this field one can get in the open access, for example, at the website of StatNano project, which has been launched with the support of Iran Nanotechnology Initiative Council (INIC).

In terms of the quantity of nanotechnology patents registered in the European Patent Office (EPO) in 2016, as to the StatNano database, Russia has been on the 29th place among 56 countries, while in the United States Patent and Trademark Office (USPTO) – has shared 21st place with Austria and Denmark among 59 countries under consideration [14, p. 36-37].

Table 2. Nanotechnology patents in EPO by countries (units).

Rank	Country	2012	2013	2014	2015	2016
1	USA	306	350	361	421	577
2	Germany	208	243	206	229	289
3	France	128	145	140	152	208
4	Japan	133	134	141	131	188
5	South Korea	49	55	73	52	105
6	UK	45	38	45	45	81
7	Switzerland	37	47	63	48	75
8	Netherlands	37	45	38	43	71
9	China	15	16	14	28	59
10	Italy	43	37	29	47	49
…	…	…	…	…	…	…
29	Russia	1	0	4	3	6
	World	1,133	1,255	1,289	1,415	2,006

Source: StatNano (2017).

Table 3. Nanotechnology patents in USPTO by countries (units).

Rank	Country	2012	2013	2014	2015	2016
1	USA	3,041	3,615	4,414	4,365	4,316
2	South Korea	430	501	667	839	914
3	Japan	526	587	889	902	819
4	Taiwan	407	425	551	500	514
5	China	225	270	357	393	416
6	Germany	205	248	496	307	301
7	France	140	176	347	242	210
8	Netherlands	103	115	155	156	136
9	UK	60	87	145	109	123
10	Canada	82	85	127	109	106
…	…	…	…	…	…	…
21	Russia	4	4	11	8	12
	World	5,342	6,354	8,681	8,588	8,484

Source: StatNano (2017).

The actual data on the produced nanomaterials, manufactures and products with the use of nanomaterials and nanotechnology are available at the websites of the Nanowerk Nanomaterial Database™, the StatNano Nanotechnology Products Database (NPD), the Netherlands NANO Supermarket, the DaNa2.0 (Data and Knowledge on Nanomaterials) in Germany, and some others abroad, as well as the Unified Computer Database on Nanomaterials and Nanotechnologies Used in the Russian Federation (website http://web.ion.ru/GM_1/GM.aspx), and the profiled registries of the Startbase – System of Supporting and Promoting Innovation (website https://www.startbase.ru/registries/), which are held by the Fund for Infrastructure and Educational Programs (FIEP), the member of RUSNANO group.

The Nanowerk Nano catalog contains 3883 nanomaterials, including 691 nanotubes, 2617 nanoparticles, 114 graphene items, 231 quantum dots, 99 fullerenes, 83 nanowires and 48 nanofibres from more than 150 suppliers worldwide. By the end of March 2017 the StatNano NPD has monitored 79 nanomaterials produced by 1188 manufacturers in 52 countries and applied by 13 industries in 642 product types.

Among 1574 items registered in the nanomaterials section of the Unified Computer Database on Nanomaterials and Nanotechnologies Used in the Russian Federation less than 7% are evident nanomaterials (including nanopowders, nanoparticles, nanocoatings, nanoclays, nanocomposites, etc.) while the rest of items are the final products produced with applying nanomaterials or nanotechnology. The similar problem is typical for the content of the nanomaterials section in the Startbase Nanotechnology Product Registry, for the DaNa2.0, and the NANO Supermarket.

Thus, the fact is that the majority of existing foreign and Russian databases under consideration represent asymmetry, heterogeneity and even inconsistency of the information, because they list both nanomaterials, which are applied in industrial production, and final products, which are manufactured with the use of nanomaterials or nanotechnology. This makes it difficult to obtain relevant business information for manufacturers and consumers, and, therefore, hinders consolidation of nanoindustry in the Russian Federation, as well as development of national and regional markets for nano-enabled consumer products.

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