Science

Patent Landscape for Nanotechnology

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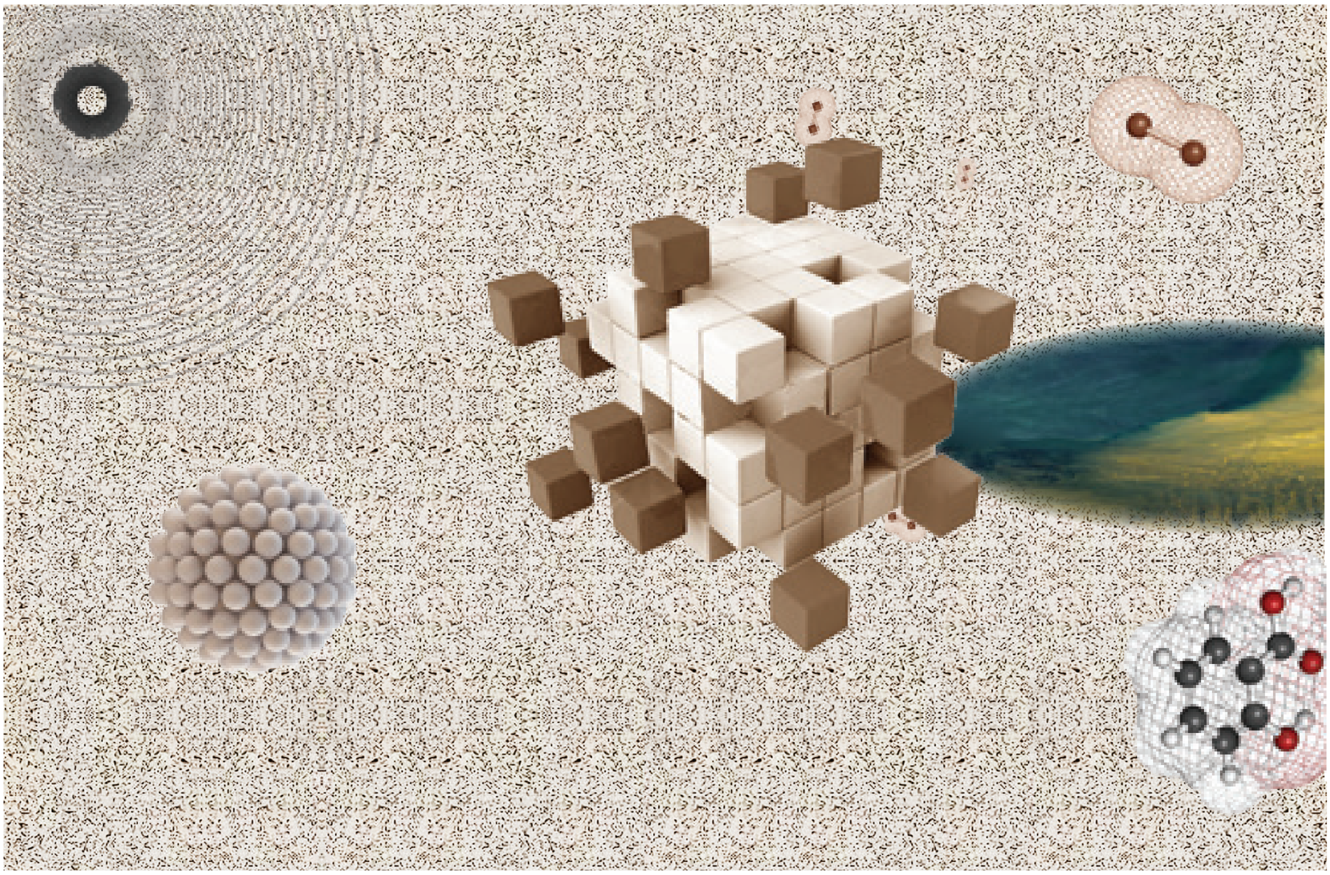

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Abstract

A methodological approach to patent landscaping for nanotechnology is considered in this paper. In the opinion of the authors, nanotechnologies have precedence over other technology trends that are confirmed by evaluation of the present and future market size of nanotechnology productions. An analysis of patent activity in Russia and the world is performed using patent landscape for nanotechnology as well as for metallurgy in the field of nanotechnology. A new methodological approach is based on a relevant patent search of nanotechnology solutions with nanotechnology keywords and relevant interdisciplinary terms. The practical significance of the methodological approach is confirmed by the activity of the Fund for Infrastructure and Educational Programs (FIEP) in terms of: the determination of the thematic scope for newly developed educational programs; the development of the joint intellectual and material recourse base for the needs of the teaching and learning activities; the selection of the potentially interested company-partners, which can provide the relevant structure and guarantee the quality of the program of manufacturing requirements and labor market.

Keywords: nanotechnology; metallurgy; patent landscape; patent mapping; index IPC; nanotechnological terms

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According to recent studies, with the industrial revolution in England, five technological waves of innovation have succeeded one another in the world's technical and economic development. The fifth wave, which dominates today and is linked to the surge in computing and telecommunications, is coming to an end in its life cycle, and in many ways has exhausted opportunities for economic growth [*Lvov*, *Glazev*, 1986; *Polterovich*, 2009]. At the same time, a sixth-wave production system — the dynamics of which will shape the global economic trends of the next two to three decades — has been slow in the making. At the centre of this wave is a complex of nano-, bio-, genetic, molecular, information and communication technologies [*Glazev*, 2008].

One of the first mentions of the methods which are now referred to by the general term 'nanotechnology' was in a 1959 talk by Nobel laureate Richard Feynman who, in his lecture 'There's Plenty of Room at the Bottom,' spoke about a 'staggeringly small world' [*Feynman*, 1960]. The term itself was introduced to the scientific community in 1974 by the Japanese physicist, Norio Taniguchi [*Taniguchi*, 1974]. In global practice, the term 'nanotechnology' is understood to refer to all of the methods used to study design and produce materials, devices and systems including targeted control and alteration of the structure, chemical make-up and interaction of individual components of nanotechnology elements at scales of 100 nm or less as the minimum in one dimension (GOST R 55416-2013; ISO/TS 80004-1:2010). These methods are helping to improve and reveal additional operational and/or consumer characteristics and properties in the products that are produced.

Technology priorities

Achieving the fifth and sixth technological waves of innovation in one form or another is specifically stipulated in the development strategies of the US, EU, Japan, South Korea, Russia, and other countries for the period up to 2030–2050. In every case, scientific research in breakthrough fields such as new materials, ICT, space, environmental, nano- and biotechnologies and medicine are listed as priorities [*Kuzyk et al*., 2011]. As a result, the role of nanotechnologies in these countries is critically high, as it is precisely with these technologies that we can conquer fundamentally new frontiers in information science, molecular biology, genetic engineering, and medicine. Investment in research and development (R&D) into various types of nanotechnologies has remained consistently high in these countries in recent years. In 2012, 18.5 billion dollars were spent on nanotechnology R&D, which is 8% higher than equivalent spending in 2010 [Lux Research, 2014]. However, there was a slight reduction in the percentage of public and private (venture) investment by 5% and 10% respectively, while corporate spending on R&D in nanotechnology grew by more than 20% [Lux Research, 2014]. The number of scientific publications and patents increased significantly and thousands of companies producing or using nanoproducts were set up. These include at least 80 consumer goods groups and more than 600 types of raw materials, components, and industrial equipment[1].

Priority of nanotechnologies

We expect nanotechnologies to have a significant impact on the global economy; a reliable indicator of which is the size of the corresponding market. Assessments of this impact depend on the adopted definition of nanotechnologies, measurements of their contribution to added value in the end product, and the level of optimism of analysts and differs by considerable amounts. Most experts, however, trace the beginning of the rapid growth of the nanotechnology market back to 2010 and outline the sectors which will have a leading role in this

[1] The nomenclature for the corresponding goods and services was adopted under Resolution No. 1192-r dated 7 July 2011 of the Government of the Russian Federation for the state to statistically monitor the production and sale of nanoindustry products and services. Rosstat Order No. 496 dated 13 December 2011 'On Approving the Statistical Toolkit for Statistical Observation of the Activities of Businesses and Organizations in the Nanotechnology Industry' made provisions for a quarterly form for federal statistical monitoring: Form No. 1-NANO 'Information on shipments of goods, work, and services linked to nanotechnologies' (with the amendments and addenda introduced by Rosstat Orders No. 232 dated 26 June 2013 and No. 547 dated 4 September 2014).

sphere in the future. It is expected that electronics, new materials, medicine, and biotechnology, and, to a lesser extent, energy and the environment, will dominate demand in the nanotechnology market in income terms [Lux Research, 2014; GIA, 2014].

Total sales of products manufactured using nanotechnologies amounted to 731 billion dollars in 2012, and by 2018 this figure is forecast to grow to 4.4 trillion dollars (Lux Research, 2014], which is equivalent to more than 5% of global GDP for 2014, compared with 0.9% in 2012 [EconomyWatch, 2015]. At least half of this figure is attributable to final products based on modern semi-conductors. This segment of the market is not classified as fundamentally new products and technologies, but rather it belongs to the previous technological wave: semi-conductor technologies transitioned from micro- to nanoelectronics and were limited to the 100 nm mark of the early 2000s. We are now pushing beyond the 10 nm frontier. The remaining sales from this figure, totalling roughly 1.5 trillion dollars, can be broken down into two parts: 5% for breakthrough technologies allowing for the development of fundamentally new products and 95% for technologies used to improve the consumer characteristics of existing products. Nanotechnologies in the second group are used in already well developed industries and account for a certain proportion of a product's final value. In order to calculate these specific values, the proportion of materials and intermediate products, which on average account for 1/3 of the good's price, are taken into account; from this figure the direct nanotechnology component is singled out: coatings, films, or powders which are used to improve the consumer characteristics of a particular good. Experts consider this share to be 10% on average. This approach explains, among other things, the actual value given in Russian translated publications for the global nanotechnology market that uses data from BCC Research & Development et al.: 12 billion dollars in 2009 and 27 billion dollars in 2015 (forecast). These assessments only take into account first-generation nanomaterials (particles, carbon tubes, new materials, and composites), nanoinstruments (lithography and probe microscopy), and nanodevices (sensors and electronics).

The priority of nanotechnologies in different countries is well illustrated by global patent dynamics [*Igami*, *Okazaki*, 2008; *Jordan et al.*, 2014]. From 2000, the growth in the number of patent applications for nanotechnology inventions exceeded overall patent dynamics. Virtually any important innovation in this field gives rise to a surge in patents. For example, the discovery and study of new allotropic carbon modifications — fullerene [*Kroto*, 1985], carbon nanotubes [*Iijima*, 1991], and forming and studying graphene [*Novoselov et al.*, 2004] — caused a wave of patents linked not only to new materials based on carbon nanoparticles, but also various types of microelectronic devices using nanotubes, graphene, etc. [*Jordan et al.*, 2014].

Patent landscape

A patent is a legal document certifying authorship of an invention, utility model, or prototype and the exclusive right to use them. It is also a unique source of science and technology information, not limited to a description of the invention, but also reflecting the level of current research and innovation long before the product reaches the market. To evaluate current trends and select areas to support in nanotechnology, extensive use is made of statistical analyses of patent activity, comparing the number of applications by region, field of application, and citations [*Igami, Okazaki*, 2008].

Another way to study the characteristics of patent activity surrounding a particular technology in a particular region or on a global scale is to analyse the patent landscape, referred to as patent landscaping [WIPO, 2015]. This method involves compiling a statistical sample of bibliographical data and analysing a large set of patent information followed by visualizing the results (Fig. 1).

In patent landscaping, technological solutions described in the patent documentation are depicted on a map in the form of isolated 'islands'. Even when there are only weak links among the general collection of documents, they show certain trends in research activity, the most popular of which are shown as large

Fig. 1. **Key stages of patent landscaping**

Source: compiled by the authors.

'continents'. The map makes it possible to see how close the 'islands' of certain patent holders are to one another and how they are distributed across the spectrum of technological solutions. Using patent data, it is possible to identify areas displaying applicant activity and changes in intellectual property portfolios both in terms of content and time, and to reveal the leading countries in various thematic areas [EPO, 2015].

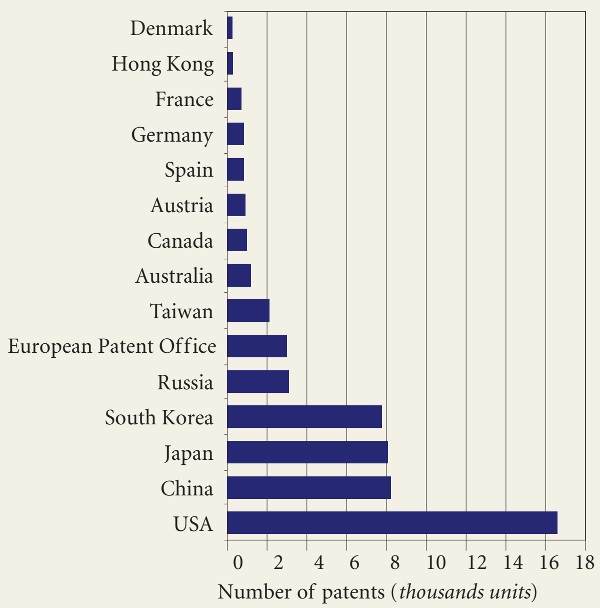
An example of effective patent landscaping is the open-access publications by the UK Intellectual Property Office (IPO) which analyze nanotechnology innovations and detail the patent activity of commercial organizations and universities in nanotoxicity, among other things [IPO, 2009]. Another example is the IPO's studies on the activity of those holding patents to materials based on graphene [IPO, 2013], where patent landscaping clearly shows the dynamics of technologies such as graphene synthesis, semi-conductors, LEDs, and memory by year and geographical affiliation of the applicant.

Our paper focuses on the sections and classes of technologies in which nanotechnology methods and microstructure innovations are used. According to the Technology Concordance Table [WIPO, 2013], technologies registered in the following International Patent Classification (IPC) subgroups are classified as 'Nanotechnologies':

- B82B — nanostructures formed by manipulation of individual atoms, molecules, or limited collections of atoms or molecules as discrete units; manufacture or treatment thereof;
- B82Y — specific uses or applications of nanostructures; measurement or analysis of nanostructures; manufacture or treatment of nanostructures.

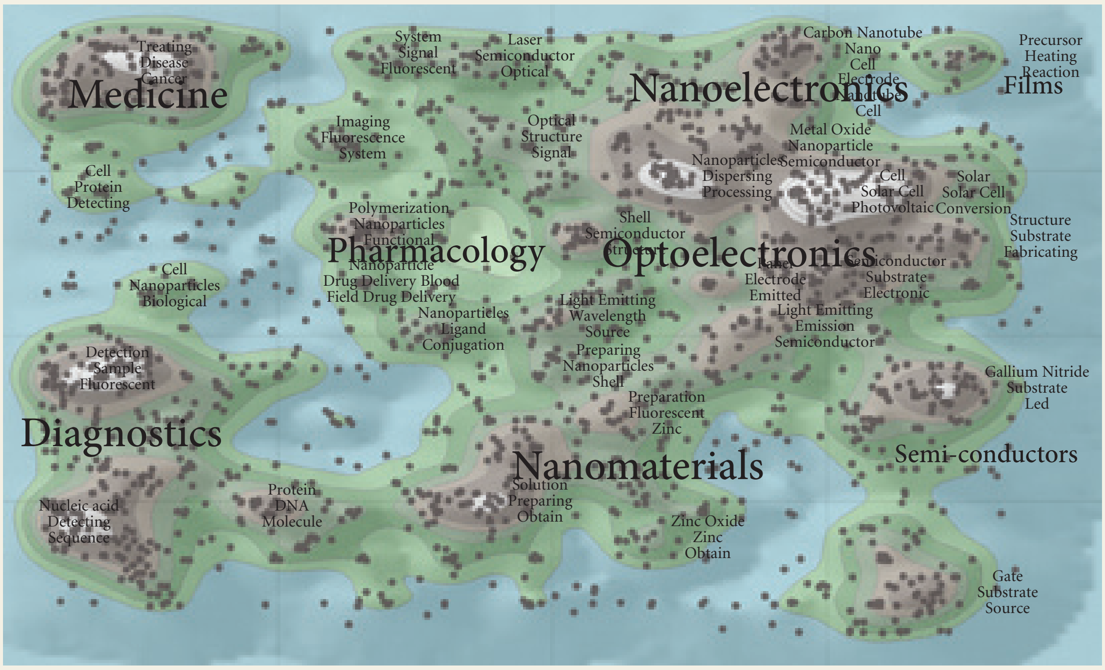
Russia's contribution to global patent activity in the sphere of nanotechnology is still relatively modest (Fig. 2). Out of the roughly 57,000 invention patents is-

Fig. 2. **Number of invention patents in the 'Nanotechnology' group by applicants' country of affiliation for the period since 1994**



Source: [Minesoft, RWS Group, 2013].

Fig. 3. **Patent landscape in nanotechnology based on subclass IPC B82 'Nanotechnology'**



Source: compiled by the authors from [Thomson Reuters, 2015].

sued by all the main patent offices globally, only 5.4% were Russian applicants. Based on this indicator, Russia occupies fifth place behind the US, China, Japan, and South Korea. The structure of nanotechnology patents held by Russian residents is homogeneous due to their orientation in the domestic market. The number of applications submitted to foreign registering bodies is low, which can be explained by the low competitive value of Russian developments and a lack of resources, primarily financial, to undergo all the necessary procedures. While Russian patent activity in microstructures and nanotechnologies over the period 2008-2013 demonstrates some growth, the proportion of inventions of the overall structure of patents published by the main Russian patent office (> 0.5%) [WIPO, 2015] shows that this field is not yet a priority.

The very task of searching for promising nanotechnology solutions is a complex one due to the following objective reasons [*Negulyaev, Nenakhov*, 2007; *Sazonov*, 2011]:

- nanotechnologies are for the most part so new that they are mostly discussed in non-patent publications; in other words *there is not enough information in patents to analyse a nanotechnology component*;
- patentable technologies, including in the nanotechnology sphere, are classified by specific experts; in other words, such technologies are subjective in many ways, which explains *the significant dispersal of patents across IPC classes;* IPC's class B82 ('Nanotechnology') is relatively new and does not sufficiently specify the technological area to which a particular patentable object belongs. Therefore, any analysis of documentation in a specific field requires the use of IPC indexes as well as other methods, such as key terms for each specific type of nanotechnology [*Porter et al.*, 2008; *Wang, Guan*, 2012].

In this paper we analyse current patent activity within the Russian Federation and across the world. We have developed patent maps of the fields in which nanotechnologies under subclass B82 are used (Fig. 3), using relevant key words (Table 1, Fig. 4), including for metallurgy separately. The data for this study were sourced from the Thomson Innovation system, which is connected to the Derwent World Patents Index (DWPI) database [Thomson Reuters, 2015]. This database contains information on more than 80 million patent publications from national patent offices in the US, Europe, China, Japan, Russia and South Korea, the World Intellectual Property Organization (WIPO) and others.

Table 1. **Terms used to search for nanotechnology solutions**

Search query	Terms
1. Nano* (with the prefix 'nano-')	nano*
2. Quantum (quantum terms)	(quantum dot* OR quantum well* OR quantum wire*) NOT nano*
3. Self-Assembly	(((self assembl*) OR (self organiz*) OR (directed assembl*)) NOT nano*
4. Terms implying the presence of 'nano-'	((molecul* motor*) or (molecul* ruler*) or (molecul* wir*) or (molecul* devic*) or (molecular engineering) or (molecular electronic*) or (single molecul*) or (fullerene*) or (coulomb blockad*) or (bionano*) or (langmuir-blodgett) or (Coulomb-staircase*) or (PDMS stamp*)) NOT nano*
5. Terms related to electron microscopy	((TEM or STM or EDX or AFM or HRTEM or SEM or EELS) or (atom* force microscop*) or (tunnel* microscop*) or (scanning probe microscop*) or (transmission electron microscop*) or (scanning electron microscop*) or (energy dispersive X-ray) or (X-ray photoelectron*) or (electron energy loss spectroscop*)) NOT nano*
6. Other terms directly related to nano	(biosensor* or (sol gel* or solgel*) or dendrimer* or soft lithograph* or molecular simul* or quantum effect* or molecular sieve* or mesoporous material*) AND (MolEnv-R)) NOT nano*

Source: [*Porter et al.*, 2008].

To filter out irrelevant data from the search queries, certain terms were excluded with the prefix 'nano': nanometer,* nanosecond,* nanomolar,* nanogram,* nanoliter,* nano-second, nano-meter, nano-molar, nano-gram, nano-liter, nanomeli,* nanophyto,, nanobacteri,* nano2,* nano3.*

Figure 5 shows the detailed thematic structure of Russian patents in nanotechnology.

Nanotechnology patent landscaping in metallurgy

To analyse technological solutions in the metallurgy industry which make use of nanotechnologies, a filter was introduced based on the following key terms:

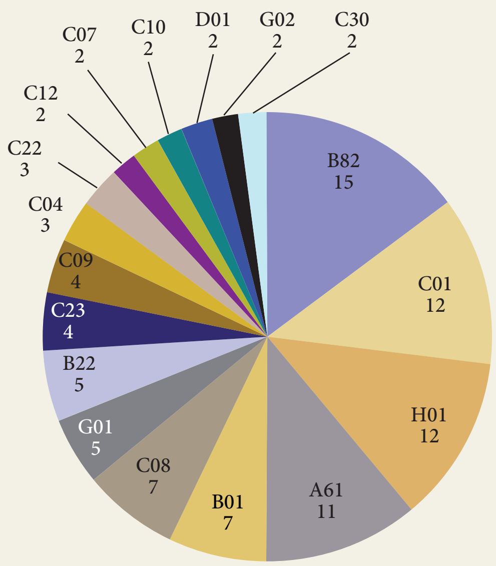
1) those linked to the presence of nanostructure elements: nano/microstructure, ultrafine grain, subgrain, crystallite, crystalline, coherent scattering region, and intermetallides;

2) those describing the controlled formation of nanostructures and properties of metals and intermetallides through deformation, thermal or combined pro-

Fig. 4. **Patent landscape in nanotechnology based on key words**

Source: compiled by the authors from [Thomson Reuters, 2015].

Fig. 5. **Distribution of patents in nanotechnology in Russia by thematic area for the period since 1994 according to the IPC indexes (%)**



		Number of patents
B82	Nanotechnology [7]	1926
C01	Inorganic chemistry	348
H01	Basic electric elements	284
A61	Medical or veterinary science; hygiene	279
B01	Physical or chemical processes or apparatus in general	249
C08	Organic macromolecular compounds; their preparation or chemical working-up; compositions based thereon	156
G01	Measuring; testing	156
B22	Casting; powder metallurgy	123
C23	Coating metallic material; coating material with metallic material; chemical surface treatment; diffusion treatment of metallic material; coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapour deposition, in general; inhibiting corrosion of metallic material or incrustation in general [2]	107
C09	Dyes; paints; polishes; natural resins; adhesives; compositions not otherwise provided for; applications of materials not otherwise provided for	92
C04	Cements; concrete; artificial stone; ceramics; refractories [4]	91
C22	Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals	77
C12	Biochemistry; beer; spirits; wine; vinegar; microbiology; enzymology; mutation or genetic engineering	61
C07	Organic chemistry [2]	54
C10	Petroleum, gas or coke industries; technical gases containing carbon monoxide; fuels; lubricants; peat	43
D01	Natural or man-made threads or fibres; spinning	41
G02	Optics	40
C30	Crystal growth [3]	38

Source: compiled by the authors from [Thomson Reuters, 2015].

cessing of special-purpose high-strength steels and alloys: microalloy, precipitation for strengthening or hardening of structures, plastic deformation, cold deformation, deformation or dispersion hardening, mechanical or deformation hardening, and strain ageing of alloys;

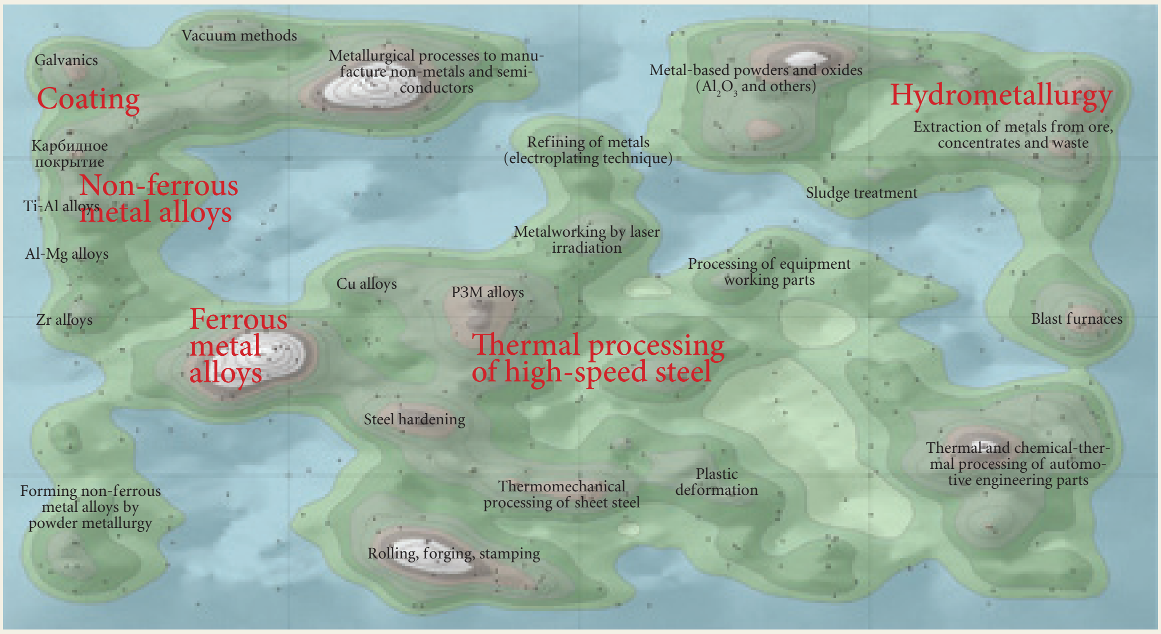
3) those used to describe other methods used to create voluminous nanostructure materials by compacting superdispersed powders that are obtained using physical or chemical methods or pulverizing in a ball mill: nano/micropowder, milling, or sintered aluminium powder (SAP).

The development of the patent landscape involved searching under the following classes of IPC section C 'Metallurgy':

- C21 'Metallurgy of iron';
- C22 'Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals';
- C23 'Coating metallic material; coating material with metallic material; chemical surface treatment; diffusion treatment of metallic material; coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapour deposition, in general; inhibiting corrosion of metallic material or incrustation in general';
- C25 'Electrolytic or electrophoretic processes; apparatus thereof';
- C30 'Crystal growth'.

The analysis covered data for all countries. The results obtained for each of these classes were compiled into a single dataset which was used to form preliminary maps representing key terms and thematic affiliation of documentation. The data were refined through additional searches in patent documents for the last 20 years. The resulting datasets were combined using the logic operator AND.

Fig. 6. **Patent landscape of IPC section C 'Metallurgy' based on key terms which may be associated with nanotechnologies**

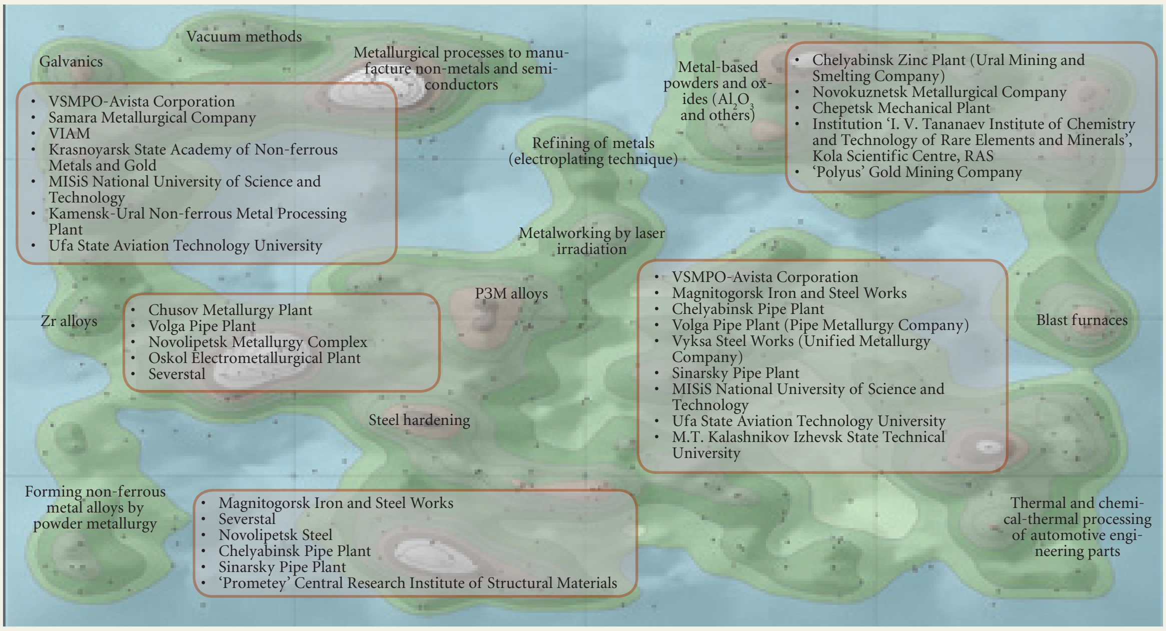


Note: Patents held by Russian organizations are shown as red points..

Source: compiled by the authors from [Thomson Reuters, 2015].

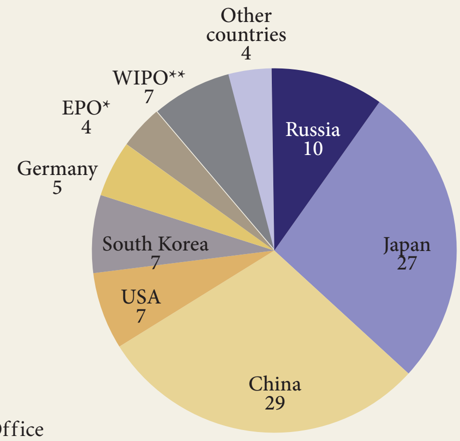
Thus, the patent landscape for IPC section C 'Metallurgy,' which shows the distribution of terms potentially associated with nanotechnologies, *was developed following an analysis of the repetition of key words in patent documents.* The relationship between the 13,198 documents containing these words is represented graphically in Fig. 6. The following map makes it possible to see how close technological fields are to one another and which technological fields the documentation datasets of various Russian patent holders belong to (Fig. 7).

Fig. 7. **Patent landscape of IPC section C 'Metallurgy' indicating the Russian patent holders**



Source: compiled by the authors from [Thomson Reuters, 2015].

Fig. 8. **Geographical distribution of global patent activity for the period 1992-2013 (%)**



* European Patent Office

** World Intellectual Property Organization

Source: compiled by the authors from [Thomson Reuters, 2015].

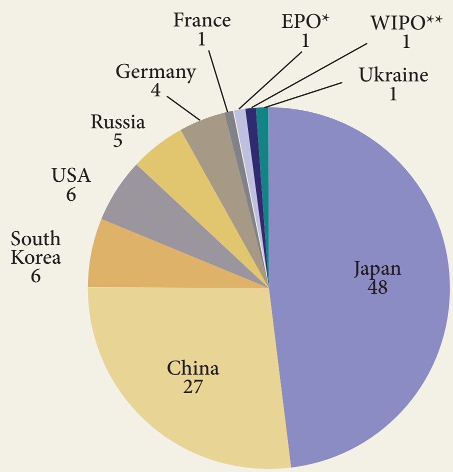
Analysis of patent documentation in metallurgy

Assessments of global patent activity in metallurgy broken down by country (Fig. 8) make it possible to locate the global leaders in R&D. The leaders are primarily China and Japan, followed by Russia, USA, South Korea, and Germany.

In Russia, ferrous and non-ferrous metallurgy (classes C21 and C22) are one of the leading areas of patent activity over the period under consideration, while in the US more high-tech fields and fundamental R&D are the priority [NBK Group, 2013]. According to WIPO data, US patent activity in the 'materials and metallurgy' area is 1.7 times higher than the figure for the Russian Federation, and in terms of patenting volumes it is more than ten times higher.

However, in some technological sectors, the number of patents in the two countries is on the whole comparable. For example, in the subclass C21D 'Thermal processing (modifying the physical structure of ferrous metals)' and C22C 'Alloys,' the number of priority applications in the period from 1992 to 2013 was roughly the same (Fig. 9). It is in these areas that the use of filters for key words

Fig. 9. **Total number of priority applications in metallurgy to patent offices in different countries for the subclasses C21D and C22C in the period 1992-2013**

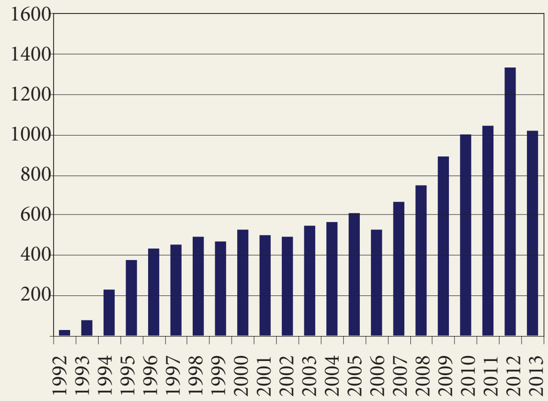


* European Patent Office

** World Intellectual Property Organization

Source: [Minesoft, RWS Group, 2015].

Fig. 10. **Patent activity in metallurgy globally**
(number of patents registered, *units*)



Source: compiled by the authors from [Thomson Reuters, 2015].

whose meanings are compatible with nanotechnology solutions reveals the comparatively high proportion of Russian patents.

The dynamics of global invention activity in metallurgy reflect the number of patent applications submitted over this period (Fig. 10). It is worth noting that over the last 15 years stable growth in patenting activity was not registered in the metallurgy industry in Russia (Fig. 11).

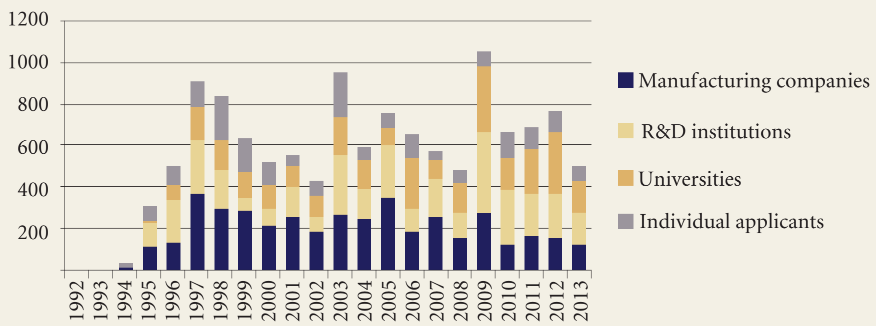
The breakdown of key technologies across all applications was based on the classification of patents under a particular IPC class — for the world as a whole (Fig. 12) and for Russia (Fig. 13).

Patent activity by Russian organizations in metallurgy

Russian players have a strong position in R&D in the metallurgy industry with a 10% share of the global patent market, behind only Japan (27%) and China (29%). Primarily, this research includes thermal processing technologies and technologies to form ferrous and non-ferrous metal alloys (Table 2).

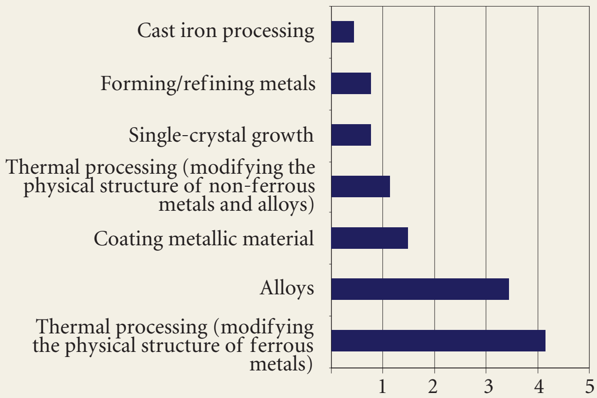
Judging by patent statistics, Russian industries are competitive in R&D in several technological areas, including: cast iron processing (Nizhniy Tagil Iron and Steel Works), modifying the physical structure of ferrous metals following thermal processing (Magnitogorsk Iron and Steel Works, Novolipetsk Steel, Severstal, and others), and forming, recovering and refining metals (Krasnoyarsk Non-ferrous Metals Plant, Krasnoyarsk Zinc Plant) (Table 3).

Fig. 11. **Patent activity and patent structure in metallurgy in Russia**
(number of patents registered by applicant type, *units*)



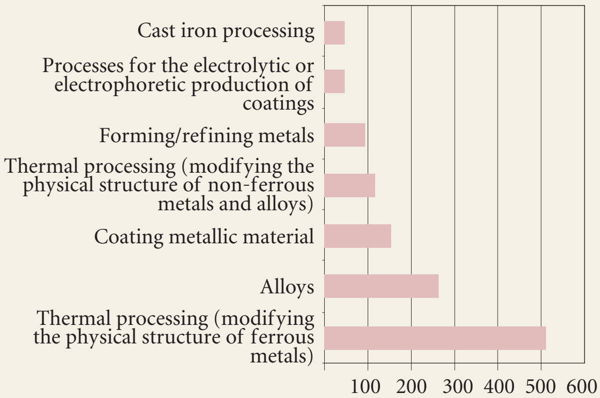
Source: compiled by the authors from [Thomson Reuters, 2015].

Fig. 12. **Key technological areas of patent activity in metallurgy globally** (number of patents registered, *units*)



Source: compiled by the authors from [Thomson Reuters, 2015].

Fig. 13. **Key technological areas of patent activity in metallurgy in Russia** (number of patents registered, *units*)



Source: compiled by the authors from [Thomson Reuters, 2015].

Table 2. **Patent activity by Russian organizations in metallurgy in key IPC classes**

IPC class	Name	Number of patents (*units*)
Manufacturing companies		
C21D	Thermal processing (modifying the physical structure of ferrous metals)	211
C22C	Alloys	69
C22B	Producing/refining of metals	31
C30B	Single-crystal growth	8
C25C	Electrolytic production, recovery or refining of metals	7
Research organizations		
C22B	Producing/refining of metals	103
C21D	Thermal processing (modifying the physical structure of ferrous metals)	90
C22C	Alloys	30
C25F	Processes for the electrolytic removal of materials from objects	15
C23D	Enamelling of, or applying a vitreous layer to, metals	8
Educational institutions		
C21D	Thermal processing (modifying the physical structure of ferrous metals)	109
C22C	Alloys	33
C25D	Processes for the electrolytic or electrophoretic production of coatings	27
C22B	Producing/refining of metals	10

Source: compiled by the authors from [Thomson Reuters, 2015].

Table 3. **Leading patenting organizations in metallurgy**

Name	Number of patents (*units*)
Manufacturing companies	
Magnitogorsk Iron and Steel Works	23
Severstal	20
Novolipetsk Steel	15
Nizhniy Tagil Iron and Steel Works	14
Sinarsky Pipe Plant	11
Chelyabinsk Pipe Plant	11
V.A. Degtyarev Plant	10
West Siberian Metallurgical Plant	10
GAZ	9
Nosta (Orsk-Khalilovsk Metallurgical Plant)	8
Research organizations	
All-Russian Scientific Research Institute of Aviation Materials	53
A.A. Baikov Institute of Metallurgy and Materials Science RAS	20
Ural Division of the All-Russian Railway Research Institute	19
'Prometey' Central Research Institute of Structural Materials	14
Institute of Metal Physics, Ural Division of the Russian Academy of Sciences	11
I.P. Bardin Central Scientific Research Institute of Ferrous Metallurgy	9
All-Russia Institute of Light Alloys	7
Institute of Solid State Physics RAS	7
'Elektrokhimpribor' Industrial Complex	7
'Salut' Moscow Engineering Production Centre	7
Irkutsk Scientific Research Institute of Precious and Rare Metals and Diamonds ('Igriredmet')	2
Educational institutions	
Voronezh State Technical University	18
Ufa State Aviation Technical University	18
MISiS National University of Science and Technology	16
I.I. Ivanov Kursk State Agricultural Academy	14
I.I. Polzunov Altai State Technical University	8
Samara State Technical University	7
B.N. Yeltsin Ural Federal University	7
Belgorod State University	6
Kaliningrad State University	5
R.E. Alekseev Nizhny Novgorod State Technical University	4
S.R. Korolev Samara State Aerospace University	4

Source: compiled by the authors from [Thomson Reuters, 2015].

Scientific research and scientific production organizations show the highest level of patent activity in the following technological areas:

- ferrous and non-ferrous metal alloys (All-Russia Institute of Light Alloys, All-Russian Scientific Research Institute of Aviation Materials, and others);
- modifying the physical structure of non-ferrous metals and alloys through thermal processing (Igriredmet and others).

The R&D of Russian higher education institutions in metallurgy is focused on technologies for coating metallic materials (Voronezh State Technical University, Ufa State Aviation Technical University, and others). The ratio of the number of patents obtained by industrial enterprises and by higher education institutions is 45% to 55%. This suggests a high level of research activity at higher education institutions, for which R&D serves as a step towards subsequent commercialization of research results and implementation of the innovation in question.

The absolute leaders in patenting scientific and technological achievements among businesses, academic and industrial scientific research institutes are the All-Russian Scientific Research Institute of Aviation Materials, the A.A. Baikov

Institute of Metallurgy and Materials Science RAS, the Ural Division of the All-Russian Railway Research Institute, and the 'Prometey' Central Research Institute of Structural Materials. The highest number of patents in the higher education sector are seen at Voronezh State Technical University, MISiS, Ufa State Aviation Technical University, and Kursk State Agricultural Academy. The Magnitogorsk, Novolipetsk, Nizhniy Tagil Iron and Steel Works, and Severstal are all implementing an active patenting policy.

Use of the patent landscape

The approaches developed in this article to assessing the current level of patent activity in nanotechnology can be used, among other things, to develop an array of programmes for further education, professional re-training, and increasing qualifications in the nanoindustry. They allow us to determine the structure and theme of new educational programmes (a thematic educational plan), partner companies who may potentially be interested in such programmes, possible developers of these programmes whose skillset in this field can be confirmed through patent portfolios, scientific publications, and corresponding scientometric indicators.

Following a comprehensive analysis of patent landscapes developed through a joint project between the Fund for Infrastructure and Educational Programmes (FIEP) and the 'Skolkovo' Intellectual Property Centre in 2014, it was possible to identify those areas of metallurgy R&D that are most in demand based on nanotechnology solutions. Taking this into account, the following areas of educational training geared towards developing the metallurgical industry can be put forward:

- construction steel with nanostructural perlite and production technology based on new high-strength viscous materials;
- nanostructured stainless steel obtained through cryogenic deformation and thermal treatment;
- nanostructured diffusion intermediate and surface layers of metal coatings that provide fundamentally higher performance characteristics for mass production of metals (tin, galvanized sheets, etc.);
- nanostructured coatings produced by vacuum application on carbon steels;
- high-performance tubular steel produced using an innovative combination of metallurgical technologies based on ultrafine microstructures;
- super heat-resistant and heat-resistant alloys based on intermetallides for next-generation aircraft gas-turbine engines that use nanotechnologies.

Patent landscaping also makes it possible to identify technological niches, which have been poorly explored at present and which hold promise from the perspective of developing start-ups, state investment, and international cooperation.

Conclusions

Our paper considered some methodical approaches to patent landscaping by using the database of Thomson Innovation and utilizing these searches to solve the problem of determining thematic educational initiatives.

Patent landscaping can serve as an effective tool to analyse the state of any technological industry, although the quality of the conclusions is directly dependent on the methodological accuracy with which the landscapes are created. A patent landscape must, above all else, reflect not only core and widely distributed technologies, but also innovative niches that have arisen in recent years. An important indicator of the demand for and the promise of a particular R&D area is the dynamics of references to terms linked to innovative technologies in patent documentation.

To carry out an effective patent search, the accuracy of the chosen key words is of critical importance, including new and interdisciplinary terms. This then makes it possible to minimize the impact of subjective appraisals when using thematic headings of patent databases.

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