Scientific and research activities in the field of nanotechnology in Poland

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Abstract

Nanotechnology is a relatively new field of science and technology, but nevertheless more and more popularized in the modern world, focused on minimization. As a new field, it requires a number of regulations in legal, ethical, social and above all scientific and technical aspects. Therefore, most countries prepare appropriate strategic documents governing the development of research in the field of nanotechnology and indicate directions and methods of funding as well as conducting research.
For the purposes of this study, the authors examined the strategic documents indicating the importance of nanoscience and nanotechnology in Poland in the research system, referring to the documents of the European Union. In addition, basing on statistical data of all Polish regions and the number of projects in the nano area, they evaluated the national scientific and research potential in the field of nanotechnology.

Keywords

nanoscience, nanotechnology, research and development potential

Introduction

Nanoscience is the umbrella term for examination and analysis of the phenomena occurring on a scale with the adopted boundaries from 0.1 to 100 nm. It means

observing matter and phenomena occurring at the atomic, molecular and macromolecular level, at which the material properties are significantly different from those at larger scales. For the purposes of this study, the use of the term nanotechnology was adopted as a term covering both nanoscience and nanotechnology.

In recent years, nanotechnology became a lever for the development of the global economy, therefore, it is necessary to effectively support this field in Poland. In the development of nanotechnology creative and intellectual potential, which are strengths of the Polish science, are needed most of all. To fully exploit this potential, nanotechnology should become a priority direction of research and also a training ground for the introduction of new organizational solutions that increase the efficiency of use of available resources. In addition, steps leading to substantial increase in the level of funding of nanoscience should be taken and the system of organization of research and education significantly improved (*Nanoscience and nanotechnology*, 2006).

The aim of this paper is to present the current state and development potential of nanoscience and nanotechnology in the context of the existing development strategies of nanotechnology and the human potential and the infrastructural research and development background of Poland.

1. Nanoscience and nanotechnology in the European Union strategic documents

The growing importance of nanotechnology in the global economy caused that the initiatives were undertaken, strategies developed, and also special programs for the promotion and development of nanoscience, which aim at stimulation of economic, environmental and social objectives, were launched. Goals, objectives and instruments of implementation of the European Union policy in respect of support to nanotechnology were reflected in the documents describing the development and forecasts of development of individual members and the regional community.

One of the main European strategic documents for nanotechnology is the EU Commission's Communication Towards a European Strategy for Nanotechnology (*Towards a European strategy* ..., 2004). This document, as one of the main objectives indicates the maintenance and strengthening of the European research and development (R & D) in the field of nanoscience and nanotechnology. Moreover, the following was indicated as key elements of the document:

- increase of investment in research and development (R & D);

- construction of a world-class competitive R & D ("poles of excellence"), taking into account the needs of industry and research institutions;
- promotion of an interdisciplinary education and training of research staff;
- ensuring favourable conditions for technology and innovation transfer;
- integration of social conditions into the R & D process at an early stage;
- countering potential threats to health, safety, the environment and consumers;
- integrating risk assessment into every step of the life cycle of nanotechnology-based products and adapting existing methodologies and, where appropriate, development of new methodologies.

According to the assumptions of the document, all the efforts to begin work on the development of nanotechnology should be supported by appropriate cooperation at the international level. In recent years we have seen an increase of financial support from the European Union, both in research and industrial applications in the field of nanotechnology. In addition, a mechanism to facilitate the obtaining of grants for companies implementing nano solutions and promoting the European production markets for nanotechnology was created (*Nanoscience and nanotechnology*, 2006). The document regulating the undertaken measures from the legal side was the developed and adopted by the European Commission Code of conduct for responsible research in the field of nanosciences and nanotechnologies (OJ. L 116, 2008).

An important role of nanoscience and nanotechnology in the modern world is also described by the documents specifying the directions of research expected for funding and development within the 7th Framework Programme (FP7). To the research in nanosciences, nanotechnologies, materials and new production technologies, the fourth thematic area of the program was dedicated. In addition, the thematic areas of the Cooperation program (Health, Food, Agriculture and Fisheries, Biotechnology, Information and Communication Technology) include provisions conditioning the development of these areas largely from nanotechnologies and their applications. According to the assumptions of FP7, nanosciences, nanotechnologies, materials and new production technologies are of great importance to the industry, and their integration for the benefit of sectorial applications can be realized, inter alia, through activities in the field of nanoelectronics, manufacturing, power generation, steelworks, chemistry, transport, construction industry, industrial safety, textile industry, ceramic industry, forest industry and nanomedicine. Among the activities that affect the development of nanoscience, was mentioned, inter alia, the creation of new knowledge of border phenomena and size dependent phenomena, nanoscale control of material properties, integration

of nanoscale technologies, including monitoring and detection, self-organizing properties, nanomotors, nanomachines and nanosystems, methods and tools for measurement and operation in nanoscale, precision technologies used in chemistry, analysis and production of nanoparts, the impact on human safety, health and environment, metrology, monitoring and detecting, nomenclature and standards, research of new concepts and approaches for sectorial applications. FP7 also draws attention to studying the impact of nanotechnology on society and the relevance of nanoscience and technology for the solution of social problems (www.kpk.gov.pl/7pr).

Almost all the developed and developing countries show a very strong interest in nanoscience and nanotechnology. National initiatives undertaken by countries such as the U.S., Japan, Canada or Bulgaria, Romania, China, award a special status to the national nanotechnology research programs, and at the same time spend relevant amounts on its development. Examples of the initiatives include: the American National Nanotechnology Initiative (www.nano.gov), the British National Nanotechnology Initiative (UK National Initiative on Nanotechnology – NION), (www.nano.org.uk), the Israeli National Initiative for Nanotechnology (INNI), (www.nanoisrael.org).

The research conducted in the field of nanotechnology in different European countries can be assigned the following characteristics (Nanoscience and nanotechnology, 2006):

- creation of networks and partnerships focused on common development and usage of the research and test equipment by research institutes, universities and industry;
- creation of the first-class research centres, acting as creators of directions of research and technological innovation;
- development of standards for nanotechnology;
- promotion of the interdisciplinary studies and research;
- strengthening of the international cooperation;
- attracting young talents.

Poland has also undertaken activities aiming at defining the role and determining the directions of development of nanoscience. They were described in the following documents:

- Nanonauka i nanotechnologia. Narodowa strategia dla Polski, Ministerstwo Nauki i Szkolnictwa Wyższego, Warszawa 2006; (Nanoscience and nanotechnology. National strategy for Poland, the Ministry of Science and Higher Education, Warsaw 2006);

- Strategia rozwoju kraju 2007-2015. Strategia Rozwoju Nauki w Polsce do 2015 roku, Ministerstwo Nauki i Szkolnictwa Wyższego, Warszawa 2007; (National Development Strategy 2007-2015. Strategy for the Development of Science in Poland until the year 2015, the Ministry of Science and Higher Education, Warsaw 2007);
- Krajowy Program Badań. Założenia polityki naukowo-technicznej i innowacyjnej państwa, Załącznik do uchwały nr 164/2011 Rady Ministrów z dnia 16 sierpnia 2011 roku. (National Research Program. Assumptions of national science, technology and innovation policy, the Annex to Resolution No. 164/2011 of the Council of Ministers of 16 August 2011).

The report *Nanotechnology and Nanoscience*. *National strategy for Poland*, developed by the Interdisciplinary Team for Nanoscience and Nanotechnology appointed by the Ministry of Science and Higher Education is a strategic document at the national level, designating priorities in nanosciences. As the main objective, it indicates achievement by Poland a significant competitive potential in the directions of research and applications by the year 2013 on an European scale (*Nanoscience and nanotechnology*, 2006). In this report, nanotechnology has been identified as one of the key factors that contribute to economic and scientific development of the country. The priority of nanoscience and technology strategies in Poland is the development, coordination and management of the national system of research, infrastructure, education and industry in this field, in the short, medium and long term, in order to maximize the positive economic, scientific and social effects.

Implementation of the strategy provides for the following purposes:

- the development of dozens of globally competitive products with high added value, using nanotechnology;
- developing and putting on the global market several dozen technologies and manufacturing equipment for the production of nanomaterials;
- creating a system of education that allows for training hundreds of professionals in the field of nanotechnology a year;
- educating at the European level about 20-30 doctors per year in nanotechnology specialization;
- creating the education system (several courses per year) in the field of nanotechnology for the benefit of higher education and a growing industry that uses nanotechnology;
- launching the specialized laboratories, being educational facilities for science and the business sector (including clean rooms, with analytical and technological equipment at the highest global level);

- establishing a number of cooperation networks composed of associated with nanotechnology units of the research sector, industry sector, financial institutions, in order to ensure effective co-operation between science and business;
- integration of a dispersed research centres activity within the framework of a common development program co-ordinated by, provided for the establishment, the Institute of Nanotechnology, or other central unit.

Another document predicting the development of nanotechnology in Poland is the National Development Strategy 2007-2015. The strategy for the Development of Science in Poland until 2015. This document indicates the formation of new multidisciplinary research areas such as ICT, the integration of biotechnology and nanotechnology, as one of the trends in scientific research, technological development and innovation activities. At the same time it points out that the dynamics of nano, bio and info is not characterized by incremental, minor improvements of the dominant pattern, but a rapid succession of completely different designs. Among the trends presented in the document, are also the slow emergence of the fusion of biotechnology and nanotechnology (or bio-and-nanotechnology and cognitive sciences) as the next techno-economic paradigm.

The assumptions of the science and technology policy and the innovation policy, set out in the National Programme for Research, include seven strategic interdisciplinary areas of scientific research and development. These are:

- new technologies in the field of energy;
- civilization diseases, new medicines and regenerative medicine;
- advanced information, telecommunications and mechatronics technologies;
- modern material technologies;
- environment, agriculture and forestry;
- social and economic development of Poland under global markets;
- security and national defence.

The records presented in the area of civilization diseases, new medicines and regenerative medicine point to new therapeutic and pharmacological features, which are inherent to the development of nano-pharmacology. A very important field in this area is also the development of nanotechnology in the search for new polymeric and lipidic drug carriers in the targeted therapy.

The area of modern materials technologies lists the nanotechnology generating new materials with structure programmed at the molecular level and completely new properties and applications as the target. The discussed document indicates that the new generation of materials designed and implemented in the production is already finding applications in the economy, and in the future should become

a "Polish specialty". To achieve this, it is necessary to use the nanotechnology in practically every area of our economy: in the production of functional materials having application in computer science, electronics, photonics, and energy, in the chemical industry, engineering industry, food industry, garment industry, construction-based industries, biomedical engineering and transport, agriculture, and defence industries. Furthermore, the development of advanced materials engineering techniques will enable the controlled development of the properties of materials and the development of energy-efficient and environmentally friendly solutions. According to the projections provided in the study, it is necessary to develop nanoelectronics, which will be an opportunity for the emergence of innovative and improved technologies improving the safety of the society, the economy and the country, materials and technologies related to the storage and transmission of energy and photonic technologies used in long distance, reliable and efficient systems for the transmission of information. Also, the ensurance of the safety, durability, usability and reliability of buildings requires the development of the new constructions and materials, safe for health and the environment, and at the same time with high durability. Nanotechnology may also be used for the development of a new generation of construction materials with high strength and thermal properties.

The documents discussed above, relating to the priority directions of the development of nanoscience, indicate its important role in the modern world. The use of the recommendations made in the strategic documents, created so far, will allow for easier creation of a vision of development of nanotechnology in the various regions of the country and the focus of work in this area. At the same time the support instruments provided in these documents can stimulate and encourage the development of nanotechnology. It is worth noting that the focus of research on nanotechnology is in line with the provisions of the strategic documents at the national and European level, relating to the development of nanoscience.

2. Nanotechnology in Polish R & D projects

The main source of funding for research in the field of nanotechnology in Poland are the resources of the Ministry of Science and Higher Education. In 2011, expenditures on research and development in Poland totalled PLN 11 687 million, representing 0,77% of the gross domestic product. They were among the lowest in the European Union (the EU average was 2.03% in relation to GDP). The dominant share of resources in expenditures on R & D was constituted by the budgetary re-

sources (55.8%), and the research and development activities were carried out by 2 220 units (CSO, 2012).

The national human resources potential in the field of the nanotechnology development process can be assessed indirectly on the basis of the number of completed grants (research, habilitation and doctoral) by Polish scientists. The analysis of the projects registered in the OPI database in the field of completed projects concerning the area of nano during the period 2006-2011 showed a clear increase of in the number of the submitted projects (Fig. 1), (osf.opi.org.pl).

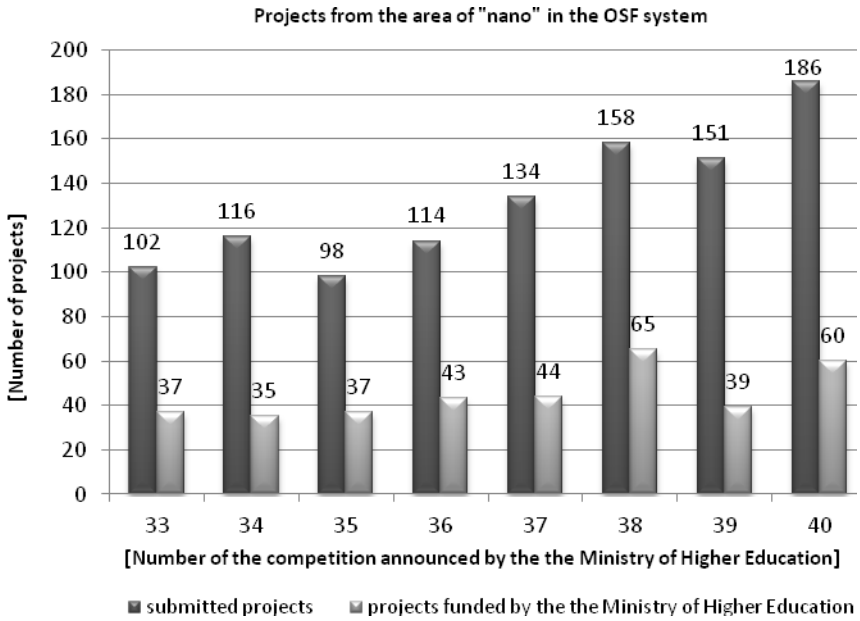

Fig. 1. Number of projects in the field of nano submitted for funding from the Ministry of Higher Education

Source: own.

When comparing data from the of competitions No. 33 and 40 in terms of the type of implemented projects it can be seen that, in accordance with the former classification the number of three types of projects increased – the so-called habilitation, promotor and own projects (Fig. 2).

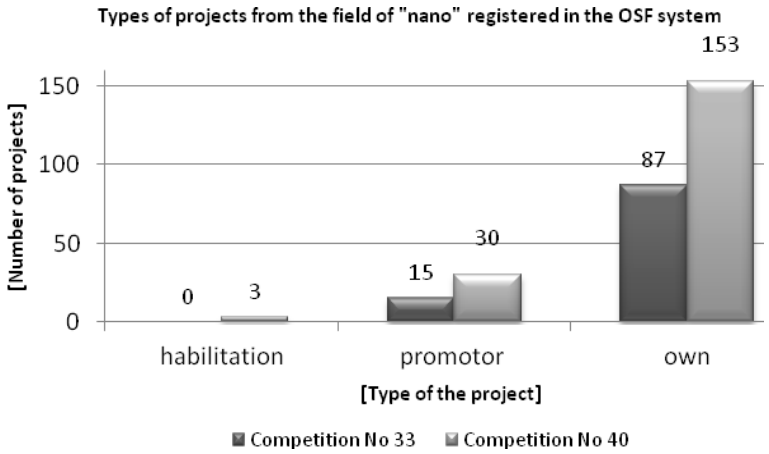

Fig. 2. Number of submitted projects from the area of nano for the Ministry of Higher Education funding, broken down by types of projects

Source: own.

Compared to the 1990-2000 period, in the years 2001-2012 the number of submitted projects increased almost tenfold (from 68 projects up to 668 projects). Among the total number of projects completed in 2001-2012 (registered in the SYNABA system) 46.0% accounted for scientific work, 34.0% doctoral dissertations, 14.0% R & D work and 5.0% postdoctoral projects (Fig. 3).

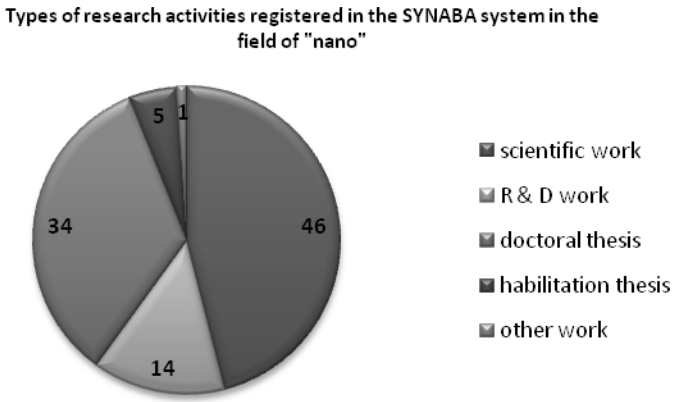

Fig. 3. Types of research activities registered in the SYNABA system in the field of "nano" [%]

Source: own.

In 2011, the Ministry of Science and Higher Education provided the funding of research projects for the newly established National Science Centre (NSC), which distributes the funds in nine competition categories (Table 1).

Table 1. Types of competitions funded by the National Science Centre

No.	Competition type	Characteristics
1.	OPUS	competition for research projects, including the financing of purchase or construction of research equipment necessary for the implementation of these projects
2.	PRELUDIUM	competition for research projects carried out by persons who are starting a career in science, without a doctoral
3.	SONATA	competition for research projects carried out by persons who are starting a career in science, holding a doctoral degree
4.	SONATA BIS	competition for research projects aimed at establishing a new scientific team, carried out by people with a degree or academic title, who obtained a doctoral degree in the period from 2 to 12 years before the application
5.	HARMONIA	competition for research projects implemented in the framework of international cooperation
6.	MAESTRO	competition for experienced researchers, for research projects aimed at implementing cutting-edge research, also interdisciplinary, important for the development of science, going beyond the current state of knowledge, which may result in scientific discoveries
7.	SYMFONIA	competition for Inter-disciplinary research projects implemented by outstanding scientists, whose studies are characterized by the highest quality, daring crossing of boundaries between different fields of science, contributing to the creation of new values and opening new perspectives in science
8.	ETIUDA	competition for PhD scholarships
9.	FUGA	competition for national internships after obtaining the doctoral degree

Source: Own study based on: http://ncn.gov.pl/finansowanie-nauki/konkursy/typy, [06.10.2012].

In 2011-2012, the National Science Centre in the announced three rounds of competition has approved the financing of 179 projects in total in the field of nano (Fig. 4).

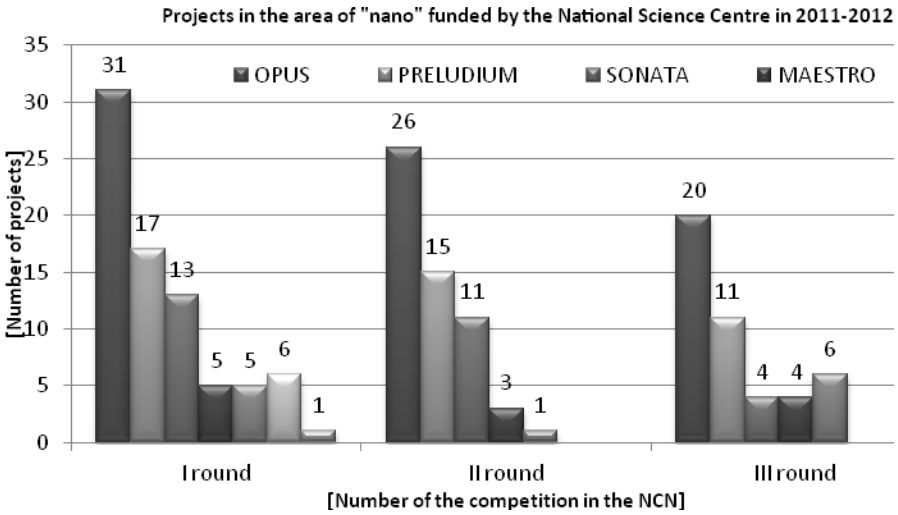

Fig. 4. Projects in the field of nano approved for funding from the National Science Centre in 2011-2012

Source: own.

The development of the national scientific potential in the area of research and development in the field of nanotechnology is currently driven by various initiatives. An example of one of them is the "FOCUS FNP Subsidies for the creation of research teams – Edition 2010 – nano-and micro-technologies in medicine" program, coordinated by the Foundation for Polish Science. The objective of the program was to support young researchers with considerate scientific achievements in the selected, annually determined by the Foundation, scientific research field which is essential for civilizational development of Poland.

In addition, the Foundation for Polish Science, within the International PhD Projects Programme (MPD) – support for units cooperating with a foreign partner in the implementation of doctoral studies, through a series of three competitions, has given financial support for the launch of doctoral studies in the field of nanotechnologies for the Department of Physics and Applied Computer Science of AGH, the Institute of Physical Chemistry of the Polish Academy of Sciences and the. Adam Mickiewicz University in Poznan. Starting doctoral programs in the field of nanotechnology is also a reflection of the growing human resources potential in the research and development field.

3. National R & D potential

The comparative analysis of the R & D potential in the provincial system showed strong regional differences in terms of indicators related to population and GDP of individual regions (Fig. 5). It was carried out on the basis of data published by the Central Statistical Office in accordance with the state for December 2011 (in relation to GDP for 2010). The analysis includes the following indicators: the share of expenditure on R & D in GDP, number of employees in the field of R & D per 1000 economically active persons, the number of units engaged in R & D activities, the number of granted patents and the level of expenditure on R & D per 1000 residents.

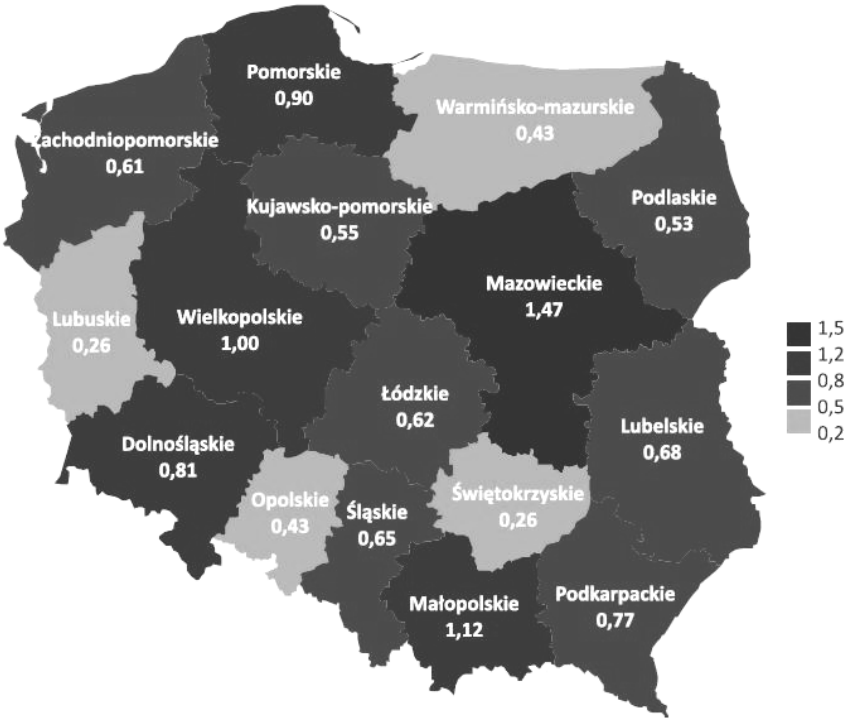

Fig. 5. Employees in R & D per 100 employed in 2011

Source: Research and development in Poland in 2011 (CSO, 2012).

The undisputed leaders in the country were: mazowieckie, małopolskie, wielkopolskie and pomorskie. The average level of expenditure on R & D in indi-

vidual regions is shown in Figure 6. The highest expenditures on R & D per capita, recorded in mazowieckie, which receives 40.3% of the total budget. Four provinces recorded a weak standing in the ranking in terms of all the analysed indicators: lubuskie, opolskie, świętokrzyskie and kujawsko-pomorskie. Research and development potential of the country is also well illustrated by the ranking of the National Science Centre on the number of projects selected for funding in 2011-2012 (Table 2).

Fig. 6. Internal expenditure on R & D per one inhabitant of the province in 2011 [PLN]

Source: Research and development in Poland in 2011 (CSO, 2012).

Table 2. List of Polish provinces, ranked by the number of projects selected for funding, and the amount of funding granted in 2011-2012

No	Voivodeships	Number of selected projects	The amount awarded [PLN]	Number of projects selected in the HS science group	The amount allocated to the HS science group [PLN]	Number of projects selected in the NZ science group	The amount allocated to the NZ science group [PLN]	Number of projects selected in the ST science group	The amount allocated to the ST science group [PLN]
1	mazowieckie	1 417	536 175 603	455	80 602 668	370	176 384 154	592	279 188 781
2	małopolskie	810	291 188 525	225	42 843 407	231	100 665 834	354	147 679 284
3	wielkopolskie	467	151 145 904	151	27 824 346	186	74 579 962	130	48 741 596
4	dolnośląskie	366	120 309 726	96	14 619 619	85	38 189 510	185	67 500 597
5	łódzkie	273	97 156 278	64	9 720 347	101	42 505 025	108	44 930 906
6	śląskie	257	86 892 133	64	8 809 825	33	12 924 192	160	65 158 116
7	pomorskie	251	97 423 947	36	6 979 891	101	50 691 605	114	39 752 451
8	lubelskie	121	25 688 835	53	4 549 341	45	14 750 693	23	6 388 791
9	kujawsko-pomorskie	113	38 397 365	34	6 478 025	31	14 581 280	48	17 338 060
10	zachodnio-pomorskie	86	28 245 209	28	3 280 865	22	12 464 335	36	12 500 009
11	warmińsko-mazurskie	78	32 628 698	12	995 776	55	29 844 906	11	1 788 016
12	podlaskie	60	14 533 917	22	2 464 565	17	5 311 531	21	6 757 821
13	świętokrzyskie	19	5 276 678	5	911 199	3	943 275	11	3 422 204
14	opolskie	16	4 359 620	5	657 199	3	1 310 740	8	2 391 681
15	podkarpackie	15	4 585 297	5	830 292	3	1 002 240	7	2 752 765
16	lubuskie	11	3 168 180	3	189 000	1	594 000	7	2 385 180
IN ALL		4 360	1 537 175 905	1 258	211 756 365	1 287	576 743 282	1 815	748 676 258

Source: http://ncn.gov.pl/finansowanie-nauki/statystyki/rankingi, [06.10.2012].

Research and development potential of Poland was, in the last five years, largely supported through the financial measures from various European Funds. Throughout the country, R & D centres were created engaged in the development of nanotechnology. These include, among others:

- NanoBioMedical Center at the Adam Mickiewicz University in Poznań (established jointly with the Medical University, the University of Life Sciences, and Poznan University of Technology);
- Centre for Nanotechnology at the Technical University of Gdansk;
- Wroclaw Research Centre EIT+ spółka z o.o.;
- Advanced Technology Centre "Nano-Bio-Info" (nBit) at the Technical University of Wroclaw;
- Research and Education Centre of Microelectronics and Nanotechnology at the University of Rzeszów;
- Centre for Bio-nanomaterials IPPT PAN, WIM PW, IWC PAN;
- BioNanoTechno Synthesis and Analysis Centre, University of Bialystok.

Summary

Poland has high class professionals dealing with issues in the area of nanotechnology. Creativity and intellectual potential are the strengths of the Polish science. In the country a base of strategic documents was created, showing the strengths and weaknesses of the development of nanoscience and nanotechnology, which may constitute a rich source of information for researchers and government deciding on the funding and research directions. In addition, with the support of the European Union funds, a number of high class nanotechnology centres, equipped with facilities for testing on a global level. To fully exploit the scientific and research and development potential, which at the moment we have at our disposal, it is necessary to define nanotechnology as a priority direction of research for the country's development, and hence introduce organizational solutions increasing the efficiency of use of available resources and a decisively increase the level of funding
of nanoscience, allowing to blur the visible borders not only between different regions of the country, but also internationally.

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Działalność naukowo-badawcza w dziedzinie nanotechnologii w Polsce

Streszczenie

Nanotechnologia jest stosunkowo młodą dziedziną wiedzy i techniki, nie mniej jednak coraz bardziej rozpowszechnianą we współczesnym świecie dążącym do minimalizacji. Jako nowa dziedzina potrzebuje szeregu uregulowań aspektów prawnych, etycznych, społecznych i przede wszystkim naukowo-technicznych. W związku z tym większość krajów przygotowuje odpowiednie dokumenty strategiczne regulujące rozwój badań w zakresie nanotechnologii oraz wskazuje kierunki i sposoby finansowania i prowadzenia badań naukowych.

Na potrzeby niniejszego opracowania autorki przeanalizowały dokumenty strategiczne wskazujące na znaczenie nanonauki i nanotechnologii w Polsce w systemie badań naukowych, odnosząc je do dokumentów Unii Europejskiej. Ponadto dokonały oceny krajowego potencjału naukowo-badawczego w obszarze nanotechnologii, w oparciu o dane statystyczne poszczególnych regionów Polski i liczbę realizowanych projektów w dziedzinie nano.

Słowa kluczowe

nanonauka, nanotechnologia, potencjał badawczo-rozwojowy