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Current state and development perspectives of Materials Science and Engineering in Poland

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Education and research trends

ABSTRACT

Purpose: The purpose of this paper is to present the current state and development perspectives of Materials Science and Engineering in Poland.
Design/methodology/approach: The actual state of affairs, further development trends, assessment of the state integration of scientific circles and proposals for the joint activities for development in the area of Materials Science and Engineering in Poland is presented.
Findings: The paper presents the assessment of the state integration of scientific circles in the area of Materials Science and Engineering in Poland.
Practical implications: The proposals for the joint activities for development in the area of Materials Science and Engineering in Poland are presented.
Originality/value: The value of this article lies in the fact that it proposes the joint activities for development in the area of Materials Science and Engineering in Poland.
Keywords: Materials Science and Engineering; Development; Integration; Research trends; Education trends

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1. Introduction

Materials Science and Engineering are the areas of science and technology employing theoretical fundamentals of the internal structure of solids for the purposeful forming of materials' properties. Materials Science is the domain of science, referring to structure and properties of materials, especially taking into account their applicability. On the other hand, Materials Engineering is the domain if engineering encompassing application of Materials Science for directly useful goals connected with design, manufacturing, and use of various products and consumer goods. The Materials Engineering

paradigm pertains selection of the engineering material, which - in the properly designed technological process of shaping the product's geometrical form, structure, and properties - will ensure the adequate, required, and assumed in advance service properties, and in consequence utility functions of the product. The main task of Materials Engineering is solving the materials problems in the advanced engineering systems, which - as products and other consumer goods get to the market deciding, in fact, the life level and quality, information interchange, education level, quality and capability of health service, and other aspects of the environment in which we live. The matter of interest of Materials Science and Engineering are materials as substances from which products of interest for customers are made, other than other chemical substances which are products of practical end use, but cannot be used for fabrication of any products, which, however, are not of interest of Materials Science and Engineering. Therefore, the most important is materials design to form their structure and properties satisfying the requirements in service conditions. The characteristic feature of Materials Engineering is its complex approach to realisation of the primary goal, which is optimising materials selection for the particular application, observing the principle of treating the basic material groups as equally important, i.e., metals, ceramics, polymers, and composites, with the multicriteria optimisation being the base for selection of the substance with the best service and technological properties, and lowest possible costs of manufacturing, processing, and service of the material and product. Fulfilling the utility function in the optimal way depends on the set of properties, and not directly on the material type. The rational selection of materials is not only the engineering problem, but also the economic, and ecological ones. The problems with which Materials Science and Engineering deal are complex and include the following general issues: atomic and molecular structure of materials, dependence of structure and properties of materials, forming structure and properties of materials, technologies of materials processing, investigation of structure and properties of materials, investigation of properties of products fabricated from materials in service conditions, prediction of materials properties, also in service conditions.

Materials Science and Engineering, apart from the computer science and avant-garde biological and medical sciences, belong to the most intensely developing areas of science, deciding currently the civilisation progress of humanity, and problems of development of Materials Engineering and - in general - Materials Science and Engineering belong to the few most important nowadays areas of science end engineering development in the contemporary world, and also as one of the most essential elements of the scientific-, scientific and technical-, and innovative policy of Poland and entire European Union within the framework of the knowledge based economy, consisting in knowledge generation, treated as production, and in distribution and practical use of knowledge and information. Therefore, production, distribution, and application of knowledge are the base of the economic development, and knowledge being a product features the main contribution to the sustainable development. The importance of the new materials and materials processing technologies development, as regards this aspect, results clearly from the assumptions and goals of the base European Union program carried out within the international cooperation framework to achieve the above mentioned state, which is the Seventh European Community Framework for years 2007-2013 (FP7) in the area of research, technological progress, and applications. Scientific research in the area of materials and Materials Engineering in Poland, directly, and more often indirectly, without financing the research within the framework of the relevant contract signed directly with the European Union, are connected with the goals and assumptions of FP.7. The merits of research defined in FP7 pertaining to the main Materials Engineering and manufacturing methods development line are comprised in the “Nanosciences, nanotechnologies, materials, and new manufacturing technologies” topic of the COOPERATION FP7 detailed program and suits well to the European policy of developing the competitive Europe. Implementations of the emerging technologies have been included to the main tasks in this area, because of the anticipated possibilities of development of the new engineering materials for the expected applications, and also of the simplification of the engineering materials processing and alternative possibilities of the manufacturing processes development in relation to the new engineering materials by specialisation (improvement of the existing materials technologies by attaining one of their main functions), convergence (attaining complex service properties by combining different engineering materials types), and integration (fabrication of the multifunctional materials using knowledge from many branches of science and technology to meet requirements of materials users and manufacturers). The IDEAS FP7 detailed program assumes supporting the most creative, interdisciplinary scientific frontier research. The new technologies development drivers, specified by the European Commission, include pressure on development of new technologies, intensification of demand for new materials and manufacturing processes, and following the sustainable development principles. The innovation effects and connected with them competitiveness of products manufacturers on the international markets are clearly dependant on integration of various advanced branches of science and technology and on attaining the synergetic effects in development of new technologies, including material ones and pertaining to forming of structure and surface properties of the engineering materials. The scope of the CAPACITIES FP7 detailed program is of the vital importance for competitiveness and maintaining the productive potential of European Union, for the inevitable strengthening of the industrial research, and introduction of new solutions for improvement of the existing production potential, in which area the importance of development of the new materials and materials processing technologies cannot be underestimated. The predicted and expected progress in the field of the advanced engineering materials, including, among others, nanomaterials (with the particularly fine structure, ensuring the unexpected so far mechanical, as well as physical and chemical properties), biomaterials (as a group of the biomimetic materials and/or making it possible to substitute the natural human tissues and/or organs directly or designed into the purpose built devices), and infomaterials (as the most advanced group of smart- and self-organising materials), and also (functional or tool ones) gradient materials (in which properties change continuously or discretely with location because of the chemical composition, phase composition, and structure, or atomic orientation changing with the location), and light metals alloys (as materials of the particular

importance, apart from the composite materials, in design and operation of the contemporary transport means).

What used to be typical of Materials Science for many years, and is typical even nowadays, has been employing the phenomenological models in many cases for description of phenomena and transformations occurring in engineering materials, for satisfying more and more complex practical requirements formulated by participants of the design process of products indispensable to the contemporary humans, including – among others - machines and devices. Materials have to be manufactured on demand today, meeting the complex set of the specific demands. This is a significant challenge for engineering materials manufacturing is expected of materials with properties ordered by products users. This changes substantially the materials design methodology in general and the products materials design, as materials have to be delivered on demand of products manufacturers with the appropriately formed structure, ensuring the required set of physical and chemical properties, and not as before when the manufacturers were forced to select material closest to their expectations from the delivered materials with the offered structure and properties, yet – by assumption – not meeting them fully, which is not permitted by this design methodology. Therefore, the actual trends force classification of engineering materials based on their functional characteristics. Currently, materials engineers participate in the products design processes and materials manufacturers have to face the requirements, as the effect of the multicriteria optimisation of, e.g., structure, properties, mass, product manufacturing and service costs, as well as of their ecological compatibility with the natural environment. These issues feature the most important contemporary requirements set to the Materials Science and Engineering. The new engineering materials and manufacturing processes are subordinated to customer needs and functional requirements of products. Fabrication of materials satisfying needs of manufacturers of market products at the right time and place is the priority of new materials technologies and manufacturing processes. Many materials design methodology activities undertaken by Materials Science and Engineering changed in this way, are connected with modelling, simulation and prediction of both the technological processes of manufacturing, processing, and forming their structure and properties, and especially of the service and use properties of materials, including those after long time service in the complex conditions, development of safe materials and products technologies, standardization of materials testing procedures, development of the prediction methodology of the new materials behaviour in service. There is a requirement for the reliable and adequate models both for materials properties prediction for fabrication of the expected products from them, and for materials life prediction, and also products made from them, after the duly planned and expected service life. Such approach guarantees efficiency of materials- and technological design, taking advantage, among others: mathematical statistics models, artificial intelligence models, multiscale modelling, and the virtual reality tools. However, development and implementation of such models calls for setting up extensive databases and knowledge bases in advance, which require wide-ranging and methodically planned classical investigations required by the Materials Science and Engineering scientific circles.

2. Actual state of affairs

Actually in Poland nearly 200 professors and nearly 250 senior academic staff members more declare their affiliation to the scientific discipline "Materials Engineering", albeit the actual number of persons that can document their title or DSc scientific degree in this discipline is slightly lower. However, one should highly appreciate the effects and education level of the scientific cadres in this area in Poland. The interdisciplinary scientific research and application tests taken up in connection with materials selection, among others by representatives of other disciplines of science, including mostly physics, chemistry, metallurgy, crystallography, machine design and operation, mechanics, electronics, bring about activity of representatives of these disciplines of science in the interdisciplinary areas connected with Materials Engineering, which - to some observers of the Polish scientific circles - gives the illusory and unfounded impression of the fuzzy boundaries between the Materials Science and Engineering areas and other scientific disciplines in Poland. Whereas, Materials Science and Engineering , as the fundamental branch of science and Materials Engineering, as the related engineering knowledge used in the industrial practice, created in the world in fifties of the last century, as a consequence of physical metallurgy development and many other branches of science and engineering during many years clearly formed their areas of interest, also in Poland. Since dozens of years the Polish scientific circles of Materials Science and Engineering are concentrated around the Committee of Materials Science active in the structure of 4th Department of Engineering Sciences of the Polish Academy of Sciences, successfully adding to development of this discipline of science, research methodology and processes of academic education and creating the scientific cadres in this area, promotion of scientific achievements of this discipline in the industrial circles and international cooperation, and in the last years even more active integration of the Polish scientific circles with the European scientific and economic structures. The Committee of Materials Science of the Polish Academy of Sciences has taken up and carries on cooperation with other Committees of the Polish Academy of Sciences, among others with Committees of Metallurgy, Machine Design, Crystallography, Mechanics, Chemical and Process Engineering, Physics. This cooperation, in the opinion of Members of the Committee of Materials Science of the Polish Academy of Sciences, does not require creation of any intermediate coordination bodies.

In Poland, scientific research connected with Materials Science and Engineering are carried out by units concentrated at Universities, Institutes of the Polish Academy of Sciences, and the Research and Development- and Industrial Institutes. Based on submissions to the competitions announced by the Ministry of Science and Higher Education for research and development projects in disciplines: "Materials Science and Engineering", "materials technologies", and "engineering of constructional and functional materials", one may assume that research in the area of Materials Science and Engineering carried out in about 50 units. A dozen or so of these units have full academic rights for awarding degrees and scientific title in the scientific discipline of Materials Engineering. These are mostly Boards of Faculty of Universities of Technology, one Board of Faculty of a University, and one Scientific Board of an Institute of the Polish Academy of Sciences. Development of the senior scientific cadres in the

discipline of Materials Engineering is assessed as correct in the Central Commission's opinion, and even above average compared with other areas of the engineering sciences. Twenty five units, including 2 higher private Universities carry out education of engineers and masters of engineering in the area of Materials Science and Engineering, and moreover, at many Universities the base or auxiliary teaching is carried out at other branches of studies in the area of fundamentals of Materials Science and Engineering and materials processing technologies. At some Universities macro faculties and unique branches of studies are offered, based on syllabus contents of the Materials Science and Engineering branch of studies. Graduates of these branches of studies guarantee continuous inflow of the young cadres for scientific work in the area of Materials Science and Engineering, mostly by PhD studies offered by many academic units and scientific institutes, organised sometimes as interdisciplinary studies. Scientific circles of Materials Science and Engineering demonstrates the satisfactory publishing activity, has its own scientific journals, as well as scientific and engineering ones with the country wide and international circulation, and participated actively through its representatives in the scientific bodies of the international scientific organisations. Several representatives of this discipline of science belong to the elite body of members of the Polish Academy of Sciences, and some are the members of the foreign or international Academies of Sciences. Speaking of the members of the Committee of Materials Science of the Polish Academy of Sciences reflect the high self-rating of the scientific activity of the domestic circles of Materials Science and Engineering. However, the topics of this research are scattered to a high extent into various centres, out of which the major part are the Universities of Technology units, and the research and development institutes, and the smallest part being the university units and the Polish Academy of Sciences ones. The scientific achievements so far are, nonetheless, extensive and valuable from the merits point of view. Many of the completed research projects have been implemented in the industrial practice.

The scientific units carrying out research in the area of the Materials Science and Engineering participate actively in acquiring means from the European Union funds. The Competition of applications for financing of research within the Innovative Economy Operating Program IEOP, Activity 1.1, carried out in 2009, may be an example. "Support for scientific research for knowledge based economy", Sub-activity 1.1.2. "Support for realisation of the state scientific-, scientific and technical-, and innovative policy by financing the strategic research programs in the thematic areas specified in IEOP". Among 122 applications which were submitted to the competition, 42 pertained to the Materials Science and Engineering area; 8 applications were connected with biomedical engineering and biomaterials, 30 with new materials and materials technologies, 4 with diagnostics of materials. Finally 28 applications were approved for realisation (23% success rate), out of which 12 were from Materials Science Engineering (1 biomedical engineering, 9 new materials and technologies, 2 diagnostics) (28% success rate). Exemplary 7 applications are listed below, which obtained financing above 20 m PLN:

1. Advanced materials and their manufacturing technologies - Institute for Non-Ferrous Metals in Gliwice - 79.6 m PLN,
2. Technologies for obtaining the biodegradable polyesters using the renewable raw materials - Centre of Molecular and Macromolecular Studies of PAN in Łódź - 43.3 m PLN,
3. Bioimplants for treatment of osseous tissue in oncological patients - Warsaw University of Technology - 31.7 m PLN,
4. Employment of biomass for manufacturing of the environmentally friendly polymer materials - Central Mining Institute in Katowice - 31.3 m PLN,
5. New constructional materials with the increased thermal conductivity - Warsaw University of Technology - 23.9 m PLN,
6. Contemporary materials and innovative methods for energy processing monitoring - Institute of Physics of the Polish Academy of Sciences in Warsaw - 22.0 m PLN.

Attempts were commenced to include the Research Area "Contemporary technologies for economy - Advanced materials technologies" in the domestic Scientific Research and Development Projects Program, approved by Minister of Science and Higher Education on 30th October, 2008, to ensure concentration of means meant for scientific activity. The program encompasses investigation and development of the new metals manufacturing technologies, their alloys and chemical compounds, functional nano-crystalline materials, laminated and gradient ones. usable ceramics, glasses, refractories, polymer materials, new semiconductors for electronics and photonics, and also search for materials with unique properties for specific applications in various branches of economy. An important element of these investigations will be development of new low-energy and ecological technologies for manufacturing and processing of the particular materials, taking into account the sustainable use of the natural domestic resources and products of the domestic chemical industry and waste recycling and management of processed raw materials, also from recycling.

Within the area of Materials Science and Engineering investigations are also carried out within the framework of the Domestic Program "Polish Artificial Heart", Key Programs, e.g.: "State-of-the-art technologies used in aviation industry" - The Centre of Advanced Technology "AERONET - Aviation Valley", invited projects, development projects, also those related to national security.

Development of Materials Science and Engineering in Poland depends not only on scientific competence, commitment, and activity of the scientific circles, its integration and co-operation, but also on the suitable State social and financial policy, which should provide conditions for the appropriate co-operation of various bodies in economy, science, and education, and on application potential of the developed engineering designs and scientific achievements. Yet, these achievements are not synchronised often with activities in the final products design and manufacturing branches, and not uncommon they are reduced to manufacturing only or even submitting a proposal of the material semi-product, as the potential offer for the manufacturer of the final products. Unawareness is common of the fact that materials manufacturing is justified only when they would be the substances with the optimally selected properties, according to the service requirements of the products. On the other hand, design and manufacturing of a product which has market potential are possible only when the most suitable materials are used for its production. Verification of the system of financing of the scientific research and of stimulation of the economic and industrial circles to realise these tasks features an essential necessary condition to attain the desired effects in implementing the scientific achievements in practice, among others in the areas of Materials Science and Engineering.

3. Further development trends

The probable development scenarios for Materials Science and Engineering are indicated in the Foresight Projects:

- National Foresight Program "Poland 2020" - Institute of Fundamental Technological Research of the Polish Academy of Sciences - Warsaw,
- Technological Foresight in the area of polymer materials - Central Mining Institute - Katowice,
- Technological Foresight in the area of Polish foundry - Institute for Foundry - Kraków,
- Development directions of materials technologies for the needs of Aviation Cluster - Aviation Valley,
- FOREMAT: development scenarios of the contemporary metallic-, ceramic-, and composite materials - Institute of Fundamental Technological Research of the Polish Academy of Sciences - Warsaw,
- FORSURF: Foresight of surface properties formation leading technologies of engineering materials and biomaterials - Institute of Engineering Materials and Biomaterials of the Silesian University of Technology - Gliwice.

Members of the Committee of Materials Science of the Polish Academy of Sciences indicate in their opinions that the horizontal area and foundation for the technologies of XXI century should be the "advanced materials" priority planned in EU 8th Framework Program. The necessity was considered important for development of Materials Science and Engineering, to concentrate the research topics, setting up technology centres and highly specialised centres for subtle investigations of the contemporary materials, additional equipping the domestic scientific centres with the unique and highly specialised scientific and research apparatus. Searching for the so called "technological and material niches" one may mention, among others: new materials for power engineering industry (renewable and nuclear), materials for medicine and biomimetic, nanostructural materials, low density materials for transport, high-temperature materials, composite materials, gradient materials, biodegradable materials and recycling of materials, as well as the remaining research problems indicated in the Research Area "Contemporary technologies for economy - Advanced materials technologies" in the domestic Program for Scientific Research and Development of the Ministry of Science and Higher Education. Further development is desired of materials design methodology with computer assistance and connected with this problem intensive development of the "Computational Materials Science" and "Computational surface engineering", as the avant-garde special fields of the contemporary Materials Science and Engineering. Surface engineering and gradient materials, also at the nanostructural scale belong to the priority areas of Materials Science and Engineering. The necessity to develop technologies recommended in the results of the National Foresight Program "Poland 2020" is unquestionable, including also the new generation of the constructional- and functional materials as well surface engineering technologies, including nanomaterials and nanotechnologies, advanced, wasteless materials technologies and biodegradable engineering materials for industry, transport, and power generation industry with the closed, safe for the environment life cycle, advanced materials and technologies for the biomedical engineering, advanced high-strength materials for industry and transport. However, members of the Committee of Materials Science of the Polish Academy of Sciences do not consider the list of these topics as complete, indicating results of other foresight projects in Poland mentioned above, and also in Europe, among others within the European Technological Foresight, declared in reports of The Future of Manufacturing in Europe (FutMan) [1] and Manufacturing Visions The Futures Project (ManVis) [2] projects. Generalisation of the European Foresight results to various new materials and various materials processing technologies is expectation for fabrication of materials ordered by products' users and the resultant need for a major change of the materials design methodology and development of research in this area, connected with modelling and simulation of manufacturing processes and prediction of the service properties of materials, development of the safe technologies of materials and products composed of the nanostructural elements, normalisation of materials' properties testing, especially of the nanostructural ones, development of the prediction methodology for the new materials behaviour in service. The need was fully confirmed for continuation of the scientific research in directions indicated in the so called European White Book, in the area of materials design, computer materials science, advanced investigation and analytic techniques, and also for manufacturing, synthesis and processing of materials, nanostructural materials, smart materials, and biomimetic materials [3]. Members of the Committee of Materials Science of the Polish Academy of Sciences regard also copper processing as one of the preferred directions of research, as Poland, being one of the main copper manufacturers, exports too few products made from this metal. The above mentioned topics of discussion held by Members of the Committee of Materials Science of the Polish Academy of Sciences indicate that the need for continuation or undertaking some of the mentioned preferred directions of research result from many source materials. The need is also indicated of a tighter, albeit not exclusive, integration of the research problems mentioned above, within the framework of the long-term state or ministerial programs, invited projects and ones coordinated by the National Centre for Research and Development and the National Centre for Science and within framework of the scientific and research consortia, to acquire the synergetic effects and increase applicability of the obtained research results and elimination of scattering the means assigned to problems which are ineffective from the research and application points of view.

4. Assessment of the state of integration of scientific circles in the area of Materials Science and Engineering

Materials Engineering as the independent branch of science dates back its development in Poland since nearly half a century. Processes of the internal integration of the scientific circles active in this branch of science, were taking place during that period, especially intensely in the last two decades. Speaking of the members of the Committee of Materials Science of the Polish Academy of Sciences reflect the high self-rating of the degree of integration of the scientific circles in the area of Materials Science and Engineering. This is because the domestic scientific circles

are highly integrated internally. Integration embraces many aspects, including joint realisation of scientific research, organisational activities within the Polish Academy of Sciences framework, as well as in scientific and also scientific and engineering associations' frameworks, publishing activity connected with publication of scientific journals in English with worldwide circulation, and scientific and engineering journals in Polish, organisation of the international and domestic scientific and scientific and engineering conferences, bilateral co-operation of various university- and/or scientific and research units.

Many joint scientific research projects coordinated within the framework of invited projects were carried, focused among others on gradient materials, materials with the intermetallic phase matrix, manufacturing technologies of products from metals and alloys with the nanometric structure, development of fundamentals of new forming technologies of products made from the hard deformable functional materials, within the framework of the "Polish Artificial Heart" project, project pertaining nanotechnology, carried out with participation of representatives of many scientific units from the area of Materials Science and Engineering. There are many examples of co-operation of research groups representing various branches of science within the Scientific Networks (e.g., KMM NoE „Knowledge – based Multicomponent Materials for Durable and Safe Performance"), joint realisation of projects within the framework of the Innovative Economy Operating Program (e.g., KomCerMet "Ceramic-Metal Composites and Nanocomposites for aviation- and automotive industry"), and many others. Co-operation of these units may be judged positively, albeit it is considered to be exploited insufficiently. There are many possibilities of its further development and integration by setting up of the highly specialised centres dealing with the selected Materials Science and Engineering topics, assembling the talented scientific cadres and considerable equipment base along with the technological facilities.

The main integrating role in the area of Materials Science and Engineering plays the Committee of Materials Science of the Polish Academy of Sciences together with Sections operating in its bosom, which co-operates closely with other the Polish Academy of Sciences Committees, including mostly the ones of Metallurgy, Machine Design, Mechanics, Chemical and Process Engineering, Crystallography, Physics, and also others in 4th Department of the Polish Academy of Sciences and other Departments. The Polish Academy of Sciences bodies, and mostly the Committee of Materials Science and its Sections organise joint meetings with specialists from other disciplines. Many scientific associations with country-wide scope are active in the area of Materials Science and Engineering, including the Polish Materials Science Society, Polish Microscopy Society, Polish Stereology Society, Polish Composite Materials Society, and with international scope, like Association for Computational Materials Science and Surface Engineering, and worldwide scope, like the World Academy of Materials and Manufacturing Engineering. These societies, carrying out their statutory tasks, participate in inspiration and evaluation of the scientific research, organise joint scientific-, and scientific and educational conferences, publish scientific journals, organise the inter-regional- and international co-operation. There is an on-going close co-operation with MRS and European Microscopy Society. Activities are integrated in the area of Materials Science and Engineering education, among others by the Conference of Deans of Faculties offering this branches of studies, albeit one should note that many units educating in this area are not encompassed by this form of integration, which - undoubtedly - affects adversely the condition of higher education in various units and in Poland in general. As much as co-operation of the Universities of Technology units, industrial- and research and development institutes at various levels, can be evaluated positively, cooperation with the university units calls for improvement. This is demonstrated at least by too small, currently, participation of the university cadres in the Scientific Committees of the Polish Academy of Sciences, scientific and engineering societies and specialist conferences, low activity of Universities in education in branches of studies in the area of Materials Science and Engineering, and having full academic rights in the field of Materials Science and Engineering by only one university unit. Materials Engineering as the interdisciplinary scientific discipline, basing on achievements of the basic sciences from the area of physics, chemistry, computer science, and crystallography, forces the necessity of such integration and co-operation, and this problem calls for intensification of the relevant activities.

The circles of Materials Science and Engineering publishes several scientific journals with the worldwide circulation, including Journal of Achievements in Materials and Manufacturing Engineering, Archives of Materials Science and Engineering, Archives of Computational Materials Science and Surface Engineering, refereed by many international refereeing institutions (as a result of co-operation between the Committee of Materials Science of the Polish Academy of Sciences, Association of Computational Materials Science and Surface Engineering and World Academy of Materials and Manufacturing Engineering), Archives of Foundry, and also journals with the country-wide scope, including among others Materials Engineering, Composites, Materials and Technologies, Polymers, Biomaterials, Welding Review. This is the impressive publication activity fully corresponding to both aspirations and needs of the scientific environment.

The Committee of Materials Science of the Polish Academy of Sciences along with its domestic and foreign partners are the organisers of many scientific conferences in Poland, including yearly Methodic Seminar on "Education and research in Materials Science and Engineering" (with the Polish Materials Science Society), every second year Conference on shipbuilding technology (with West Pomeranian University of Technology), STERMAT (with the Polish Stereology Society), surface engineering (with Częstochowa University of Technology), Seminars of Young PhD Students (with Academy of Mining and Metallurgy), conferences organised also by other organisations, like Composites, Composite Materials, Polymers, Recycling of polymer materials, and the international ones - every three years Advanced Materials and Technologies (with the Committee of Metallurgy of the Polish Academy of Sciences), every three years Applied Crystallography ICAC (with the Committee of Crystallography of the Polish Academy of Sciences), yearly Achievements in Mechanics and Materials Engineering AMME (with the World Academy of Materials and Manufacturing Engineering), yearly Contemporary Achievements in Mechanical, Manufacturing and Materials Engineering CAM3S (with the

Association for Computational Materials Science and Surface Engineering, and the World Academy of Materials and Manufacturing Engineering), yearly Symposium of the European Materials Research Society MRS, every second year Congress on Materials and Manufacturing Engineering and Technologies COMMENT (with the Association for Computational Materials Science and Surface Engineering, and the World Academy of Materials and Manufacturing Engineering). The scientific conferences mentioned above feature a very good forum for exchange of experiences and for presentation of achievements and the form of the advanced international co-operation.

Based on the analysis of the current state and integration directions on the area of Materials Science and Engineering, in spite of the high assessment in general, one may formulate the comment pertaining to the urgent need and necessity to increase integration and mutual co-operation of the scientific circles – Universities of Technology, university, the Polish Academy of Sciences units, and branch institutes in the area of research focused on materials and integration of the scientific circles with the industrial institutions, and also the need to extend the scope and form of co-operation with circles of other scientific branches, however, observing the independence and uniqueness of each of the integrating circles, including the Committee of Materials Science of the Polish Academy of Sciences.

5. Final conclusions and proposals for the joint activities for development of Materials Science and Engineering in Poland

Scientific research connected with Materials Science and Engineering are carried out in Poland by about 50 units, out of which a dozen or so have full academic rights for the independent creation of the scientific cadres. The scientific achievements, to date, are extensive and valuable from the merits point of view. Many of the completed research projects have been implemented in the industrial practice. Processes of the internal integration of the scientific circles in the scientific discipline of Materials Engineering in Poland, within the framework of the Polish Academy of Sciences and scientific-, and scientific and engineering societies, continued since nearly half century, have achieved a high level in the area of co-operation and joint realisation of scientific research, publishing activity, organisation of scientific-, and scientific and engineering conferences, bilateral co-operation of various units.

Based on analysis of the current condition, development- and integration directions in the area of Materials Science and Engineering one may formulate the following final conclusions:

1. The priority development directions should be assumed for scientific research in the area of Materials Science and Engineering indicated herein, based on proposals made by Members of the Committee of Materials Science of the Polish Academy of Sciences and available source materials, namely:
   - development of manufacturing technologies of materials with the properties specified by users of products, and of prediction methodology of the engineering materials behaviour along with development of the computer aided materials design and computational materials science, connected with modelling and simulation of the manufacturing processes and prediction of the service properties of materials,
   - development of the low-energy and ecological technologies for manufacturing, production and processing of metals, their alloys, and other constructional materials, taking into account the sustainable use of the natural domestic resources and products of the domestic chemical industry including, among others, materials with unique properties for the specific applications in various economy branches, including the low density materials for transport, high-temperature materials, including materials for composite materials, gradient materials, biodegradable materials and recycling of materials, power engineering industry, also renewable and nuclear, copper alloys, polymer materials, usable ceramics, glasses, refractories, foams and highly porous materials, composite materials,
   - development of the surface engineering technology, laminated and gradient materials, also in the nanostructural scale,
   - development of the safe technologies of materials and products composed of the nanostructural elements, nanotechnology, and nanostructural materials,
   - development of the advanced materials and technologies for biomedical engineering and medicine, and biomimetic materials,
   - development of the advanced, wasteless materials technologies and biodegradable engineering materials for industry, transport and power generation industry with the closed, safe for the environment life cycle, and waste recycling technology and management of processed raw materials, also from recycling, including materials recycling,
   - development of the advanced functional materials and infomaterials, including the smart materials, semiconductors, for electronic and photonics,
   - development and normalisation of the advanced investigation and analytic techniques, and also for methodology of investigation of properties of engineering materials, especially of the nanostructural ones.
2. The relevant level of social awareness level and of influence on the political and economy spheres governing the State and its economy should be acquired to make it evident that competing in the world markets without development and improvement of the manufacturing process is impossible, and policy of purchasing of new technologies without their improvement is very short-sighted. The relevant economy and technological stimuli should be elaborated to attract attention of the domestic industry to the need to implement the contemporary technologies based on the domestic scientific and research projects and stimulate the science-industry and industry-science co-operation.
3. Thematic scientific consortia should be established among the various research centres for realisation of the particular research problems (invited research-, target-, and research projects) or consortia for realisation of the long-term research

tasks. Specialists dealing with basic research should be introduced into the particular research teams in the area of Materials Science and Engineering, developing centres and consortia specialising in characterising materials with the contemporary structure and properties investigation methods, concentrating in them the state-of-the-art apparatus and specialised scientific and research cadre.

4. The concept should be worked out for dividing the financial resources for acquiring the specialist scientific and research apparatus and equipment, taking into account the current cadres and methodical experiences of the particular scientific centres and possibility of paying the highly specialised research services along with rules for their accounting. Uniform and clear rules should be worked out for the financial clearances for the centres constituting scientific consortia or research centres independent from their internal regulations. Motions should be made to the European Union through the scientific consortia for financial resources both for the means needed to realise the research topics and for the investment means.
5. The educational offer for the young generation should be developed and extended in the area of Materials Science and Engineering in various units, among others in the university ones, developing the new forms of teaching the specialists, including the Distance Learning method and in the areas of Materials Development, Nanotechnology, and Computational Materials Science.
6. The current co-operation forms should be continued, strengthened, and modified, as regards co-operation between the Committee of Materials Science of the Polish Academy of Sciences and other Scientific Committees of the Polish Academy of Sciences for both the basic sciences and engineering ones (among others Metallurgy, Machine Design, Mechanics, Chemical and Process Engineering, Crystallography, Physics, and also others in 4th Department of the Polish Academy of Sciences and other the Polish Academy of Sciences Departments), however, observing the independence and uniqueness of each of the integrating circles, including the Committee of Materials Science of the Polish Academy of Sciences and without the need to establish any intermediate coordinating bodies. Scope should be increased of integration and co-operation of the scientific circles – Universities of Technology, university, the Polish Academy of Sciences units, and branch institutes in the area of research focused on materials and integration of the scientific circles with the industrial institutions.

Realisation of the policy set forth above should be stimulated at the country scale by the existing scientific committees, headed by the Committee of Materials Science of the Polish Academy of Sciences as the coordinating unit, scientific and research societies active in this area, and the National Centre for Research and Development and National Centre for Science, which should not only stimulate the current research topics, but also work out the detailed modifications of the resent condition. Therefore, the currently existing societies and the Polish Academy of Sciences committees, including the Committee of Materials Science of the Polish Academy of Sciences should be maintained, however, empowering their authority and position with greater decision making competences than possessed by them nowadays.

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