

Report on the activities of the Institute for Nanomaterials, Advanced Technologies and Innovation during the NPUI project

In the period of 2014 – 2018

Miroslav Cernik



The basic characteristic of CxI activities in 2014-2018

The Institute for Nanomaterials, Advanced Technologies and Innovations (CxI) began its activities in 2009 as a sophisticated university research center with an emphasis on the applicability of R&D results in practice within the OP VaVpl project “Center for Nanomaterials, Advanced Technologies and Innovations” (2009-2013). In connection with this project, the project “Development of the Institute for Nanomaterials, Advanced Technologies and Innovations” was launched in 2014 within the NPUI program, which aimed to stabilize CxI activities in areas of material research and advanced technologies. In the period of 2014-2018, CxI became one of the leading workplaces in the Czech Republic in several areas, an important partner for industrial companies and also enrolled in the international research area. This can be demonstrated by contracts with more than 140 industrial partners, participation in 130 national and 9 international R&D projects, which were solved in cooperation with industrial partners during this period. The total volume of contracts for contractual research was more than 202 million CZK, which indicates a significant social contribution of CxI to the Czech industry and society. CxI continues in this trend and has its visions and plans clear for the future.

Main research directions

CxI employees worked on 130 R&D projects in various areas of material research and advanced engineering during this period. The basic growth of CxI was set by the project “Development of the Institute for Nanomaterials, Advanced Technologies and Innovations” within the NPUI program (LO1201). The project aimed to support high-quality research teams established at CxI. Topics included creation and application of nanostructures and their properties management, measurement of physical processes in complex environments, mechatronic elements, components and constructions, technologies for industrial use of new materials, energy in hybrid power units and technologies and equipment for the production of fibrous and nanofibrous structures. The project has produced 6 patents, 36 impacted articles and many other applied results. As an example of the project results with real practical application, we can mention new ways of nanofiber preparation, namely coaxial electrospinning, spinning with the help of alternating electric field or preparation of nanofibres with core-shell structure, which led to industrial applications.

Specific directions of CxI development were:

- Area of polluted water treatment. This area represents one of the key areas of CxI functioning and is connected with solving a large number of projects, of which we select one Czech and one international as a characteristic.
 - Center of Competence - Environmentally friendly nanotechnology and biotechnology for water and soil remediation (TE01020218) represents



activities in this respect on a national scale. CxI TUL was a co-beneficiary and an important partner in an eight-year-long project, whose subsidy volume for the period under review was less than 25 million CZK. The aim of the project was to apply new technologies for water purification based on nanotechnologies (applications of nanoparticles of elementary iron and nanofiber materials) and biotechnologies (supported by aerobic and anaerobic degradation of organic pollutants) in Czech Republic locations. Results are the development of these methods into practice, several practical applications in real locations and related results such as patents, proven technologies and impacted scientific articles.

- The project “Taking Nanotechnological Remediation Processes from Lab Scale to End User Application for Restoration of a Clean Environment” represents these activities internationally. During the FP7 EU project, which aimed at the application of nano-remediation technologies in practice, the CxI staff were responsible for WP2 “Design, Improvement and Optimized Production of Zero-Valent Iron Nanoparticles (nZVI), but actively participated in the application of technology to sites in Europe. This activity is linked to other international and national projects.
- Environmental risks of nanomaterials. This direction is connected with work on several international projects from which for the purpose of characterization we choose:
- The international project “Nanomaterial Fate and Speciation in the Environment” represents research in the area of nanomaterial risks. The project aimed to create an integrated framework of models and protocols for the Exposure Assessment Framework of nano-products. The project focused on methodology, determination of key parameters and creation of models of the fate of nanoparticles in soil, water and air. This approach is of purely practical importance because the uniform approach to the risk assessment of nanomaterials will enable the industry to obtain comprehensive data on the diversity of behavior of industrial nanomaterials and thus a standard acceptable for their regulatory registration. This activity is linked to other international and national projects.
- The area of advanced engineering is very wide. From many directions we choose the automotive industry as an example of these activities:
- CxI joined the Josef Blažek Competence Center of automotive industry, whose aim was to innovate in the construction of vehicles and powertrains with internal combustion engines and electric motors to reduce fossil fuel consumption and emissions, maximize safety, comfort and driving pleasure, adapt to legislative requirements, interact with infrastructure and other vehicles as well as allow for competitiveness in developing markets. Activities continue today in the project "Electromobility" ("Modular Platform for Autonomous Chassis of Specialized Electric Vehicles for Cargo and Equipment Transport"), in which CxI intensively cooperates with the Faculty of Mechanical Engineering.

Contractual research



R&D Center CxI was established as a university research center with an emphasis on the applicability of research and development results in practice. The research center program was funded by the European Regional Development Fund (ERDF) and calculated that the established workplace will cooperate within TUL with mainly technical faculties and ensure the transfer of research results into industrial business practice. The core of established centers was intensive cooperation with local (Czech and European) manufacturing companies. This direction of CxI was reflected both in the number and volume of national R&D projects and in the amount and structure of contractual research and economic activities of CxI. Therefore, contractual research is understood at CxI as a basic indicator of the successful operation of the center and CxI has a system for supporting and monitoring this indicator. During the reporting period, the cumulative contractual research amounted to 202 million CZK, which makes the center one of the most successful centers in the entire program of research centers. Research programs, both competitive engineering and material research contribute to this result. Competitive engineering is represented for example by analysis of suitable materials for the production of special prototypes using 3D printing, preparation and testing of parts using long carbon fibers or tests of transmission and drive units for the automotive industry, in which CxI cooperates with the Faculty of Mechanical Engineering. In the area of material research these are represented by the development of materials for the production of nanofibres, the development of models of electrospinning equipment for the preparation of combined composite materials from nanofibres (cooperation with the Faculty of Textile), special laboratory tests of alternative remediation methods for specific locations (cooperation with the Faculty of Economics) for fracture modeling or radioactive waste repositories (cooperation with the Faculty of Mechatronics). Complementary economic activity is also important, where CxI uses the knowledge of workers for mostly minor orders from industrial partners (e.g., chemical and biological analyzes within an accredited laboratory, engineering - cutting, 3D prints and construction work, service work, training and lecturing). Although this activity amounted to 31.5 million CZK over the period under review, it is more important that this activity very often starts the chain of cooperation: complementary activities → contract research → joint projects → common application outputs.

Other CxI activities involved in the management

In addition to funding from project and contract research, CxI's income was derived from additional activities, innovative vouchers from various regional authorities, donations, rent from external partners, sold licenses and know-how in the sum of over 50 million CZK. Additional activities, smaller contracts (e.g. chemical and biological analyzes within the accredited laboratory, engineering - cutting, 3D printing and construction work, service work) amounted to 31.5 million CZK. This activity often starts the chain of cooperation:



complementary activities → contract research → joint projects → common application outputs. An example of a sold license is the Picatec's patent on car body protection. CxI also solves several innovative vouchers for industrial partners every year. These innovative vouchers are important to be seen as the first step in the above mentioned process of cooperation with the industrial sector. Income from rentals and gifts amount to 350 resp. 400 thousand CZK per year and therefore in terms of management play an insignificant role.



RESEARCH RESULTS

Results of applied research

In terms of application potential of CxI results it is important to mention 46 granted patents, 3 European and one Japanese, 3 industrial designs, 56 utility models, 25 prototypes, 91 functional models, 3 certified methodologies, 4 accredited methodologies, 8 software, 3 pilot plants, 18 verified technologies and 96 other results, as well as over a hundred publications in impacted journals. The most important contribution is the created materials and technologies, which are already being used or will be used in practice in the very near future. Examples of results leading to specific applications are:

1. The first area is the preparation and use of nanofibers in various applications. CxI has been involved in research and implementation of AC spinning technology (AC electrospinning) in this field. The method developed in cooperation with the Faculty of Mechanical Engineering and the Faculty of Textile Engineering is more efficient in terms of production and the resulting fibers also have a different structure. The whole process was awarded the Gold Medal at the International Engineering Fair in Brno (2017). The result is for example the cooperation with Nanoprogress association.
2. A very important field where CxI is very active are membrane technologies based on the use of nanofibers. Nanofibers are created from proven materials (e.g. PVA) or new methods of green chemistry (renewable natural materials, biocompatible and biodegradable). Applications include water, air, acoustics, regenerative medicine and drug transport, biotechnology and remediation technologies. An example might be the project "Highly functional nanofiber dressing material with barrier function and active drug release" (MPO FV10605).
3. Another area is the use of materials (nanomaterials) and new technologies in the field of contaminated water and rock environment treatment. In the field of nanoremediation CxI has profiled itself as one of Europe's leading workplaces, which is best illustrated by the number of international projects solved around this topic (5). This applies in particular to the application of elemental iron nanoparticles (nZVI) for the purification of waters contaminated with chlorinated substances, where the relevant technologies are fully used in the remediation practice. An example could be the patent "Method of in-situ remediation of rock environment contaminated by harmful chemical compounds" (Černík, Nosek, Kvapil).
4. In the field of advanced technology CxI has established itself in addition to the above-mentioned AC spinning, with a wide range of 3D printing methods in rapid prototyping. The work also covered the preparation of new materials and their testing. Materials used in the formulation were used to test the production of specific parts for specific applications. This technology has a large number of industrial partners and a large amount of contract research (e.g. cooperation with Barum Continental).
5. Development in the area of information technology. Recently CxI has developed software tools for various industrial applications. An example is a cooperation with Trask Solutions a.s. on car-sharing software.



Significant results of applied research with non-economic impact on society

CxI does not only deal with projects, contracts and additional activities that have a direct economic effect but from the base of its statute being a part of the university also deals with the whole-societal topics with a much broader impact. Such activities are, for example:

1. As mentioned above, the issue of water purification is of great societal importance in addition to the economic effect for those operating in this field, since the application of efficient and affordable environmental technologies is highly desirable in the social context. Moreover, this importance is growing at the present, when a large part of the territory not only in the Czech Republic suffers or is beginning to suffer from a lack of groundwater. The results of this research are applied by companies active in the field of remediation of old ecological burdens, in the field of water treatment of various types of water, etc.
2. CxI also studied the possible impact of nanoparticles on aquatic and soil microorganisms to assess their potential ecotoxicity. This research can on the one hand help to reduce the established fear of nanotechnology and on the other hand set up valid tools to assess this potential toxic effect. These issues were also addressed in the above-mentioned international research projects. An example is EL-TEMSAH, Y., etc. DDT degradation efficiency and ecotoxicological effects of two types of nano-sized zero-valent iron (nZVI) in water and soil. *Chemosphere*. Elsevier, 2016, vol. 144, No 2. pp. 2221 - 2228. ISSN 0045-6535. IF 3,698, quoted 24x.
3. Another social issue addressed by CxI is the area of depleted nuclear fuel storage. Concerning this issue, CxI deals with rock environment modeling, radionuclide migration and the issue of biologically supported corrosion of storage files. In addition to economic importance, this research has a social significance, as the localization of the repository is accompanied by very sensitive environmental and social issues.
4. CxI organized five international conferences during the period under review, the importance of which is both for the presentation of research results of CxI and the whole TUL (participation of faculty representatives) as well as for establishing cooperation in the Czech Republic and abroad. From the viewpoint of society as a whole, it is the right direction of research in the given areas.
5. In addition to licensed patents CxI has produced many patents and other applied results that are not subject to economic exploitation but serve to retain certain know-how, which can then translate into research projects or contract research. Therefore, these results are important without their economic impact.

Examples of cooperation between CxI and industrial partners

Users of research results at CxI can be divided according to research areas. A few examples are given here:

- The field of remediation of old ecological burdens - users of results are consulting and engineering companies operating in this region (e.g. Aquatest a.s.).
- The field of purification with the help of membrane technologies - users are companies dealing with water, air, heat recuperation, etc. - an example is Recutech.



- Automotive industry - here the area of activities is very wide, from testing of powertrains, through prototyping by 3D printing, emission problem, windscreens etc. - an example is Škoda Auto.
- Mathematical modeling - an example is the use of flow models for the radioactive waste repository - partner SURAO.
- Industrial application software - an example is Car-sharing for TRASK Solutions.
- The field of fire protection systems - for example, cooperation on the manufacture of fire-proof door with JAP Jacina.
- Nanofibers application area - a very wide range of applications ranging from medicine, acoustics, to thermoregulation and thermo-insulating textiles - an example is the development of textiles for specific climatic conditions for Grade Medical.
- The area of thin films for improving the surface properties of materials - here, for example, the development of the innovative cutting tool with nanoparticle surfaces for Karned Tools.
- Energy sector - as an example is the study of the use of geothermal energy, both from deep wells and energy storage to surface structures, e.g. for the company Geotechnika.
- Electromobility - e.g. industrial research and experimental development of a small urban electric vehicle.

System and support of technology transfer and intellectual property protection

The commercialization system is managed by the Technology Transfer Support Center at the level of Vice-Rector for Science and Research, which provides administrative and legal activities related to the protection and deals concerning intellectual property. The executive component of the system is coordinators and technology scouts at individual faculties and CxI. The decision-making function is performed by the Commercialization Board with the Rector of the University. The system of commercialization is financed mainly from its own resources and is further supported by the projects TG01010117 - PROSYKO - "Proactive system of commercialization at the TU in Liberec" (2014-2019) and "Effective technology transfer process at the Technical University of Liberec" (CZ.02.2.69)/0.0/0.0/16_014/0000631), which mainly deals with education and is complementary to the PROSYKO project. The principal sources are mainly revenues from contract research and sales of license fees, sales of patents and utility models.

The most significant awards for R&D&I

- Visionary 2018 Award for a system for sampling and analyzing samples of microorganisms occurring on insulated facades combined with the design of solutions to eliminate their harmful effects.
- Gold Medal at the International Engineering Fair in Brno (CZ) for the production line of a linear composite material containing nanofibers, 2017



Recognition by the international community in the R&D&I area

The core of CxI's activities is to support the industry and to apply research results in practice. Since these activities are often not possible to be conducted without their own research, some CxI staff are significantly involved in publishing and related activities. These are primarily employees who directly participate in teaching students (through individual faculties of the TUL) or lead students of doctoral study programs (mainly the university-wide field of Nanomaterials). Therefore, some CxI members are members of the editorial boards of magazines (e.g. Ecological Chemistry and Engineering S journal with IF = 1.47). More staff are involved in review activities for various scientific journals (especially junior researchers).

CxI staff members attend scientific conferences, seminars, are members of various delegations and visits. In the period under review, they made dozens of visits to universities, research institutes and companies. Part of these visits were mostly presentations of the TUL, CxI research center and specific scientific activities. The most significant were presentations at international conferences or seminars, where CxI employees were in the role of "plenary speaker" or "key-note speaker". These presentations of the results of scientific work led to joint research activities, joint research projects (EU projects) and joint publications.

The Center was also involved in several projects aimed at exchanging our researchers and receiving researchers from other institutes. Within these projects, a large number of leading scientific capacities, as well as practitioners, came here. CxI also organized 5 international conferences, where leading experts from abroad also presented their results.

