

**SELECTED
RESEARCH FINDINGS
OF AN INNOVATIVE
NATURE**

**POLISH UNIVERSITIES
AND INSTITUTES
OF THE POLISH ACADEMY
OF SCIENCES**

Warsaw 2007

SELECTED RESEARCH FINDINGS OF AN INNOVATIVE NATURE

Polish Universities and Institutes of the Polish Academy of Sciences

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Foreword

This catalog of selected research achievements made by institutes affiliated with the Polish Academy of Sciences and by Polish universities has been published at the initiative of the Polish Embassy in Luxemburg, which is holding a seminar for representatives of Luxemburg's business and economic communities in November 2007.

The selected findings presented here are innovative in terms of their applications, and after further development or refinement they may be harnessed in industry or the services sector. The uses of these achievements may indeed be multiple: they may be implemented by industry as new products or as new research methods for evaluating the quality of products or services.

The achievements highlighted herein have been selected from among various projects submitted by universities and institutes of the Polish Academy of Sciences, in response to a request from the Conference of Rectors of Academic Schools in Poland (KRASP) and the President of the Academy. The selection process has striven to ensure that only high-caliber, highly-innovative research projects are showcased.

For ease of use, this collection of research findings has been divided into four categories: technical sciences, physical and chemical sciences, biological and medical sciences, and earth sciences. Aside from giving the authors' names and the names and addresses of the universities and institutes involved, each project listed here provides a technical outline of the outcome of research plus selected economic information concerning its application. It is our hope that these research profiles will aid interested individuals or institutions in making the best choices.

However, note also that the findings published herein reflect just a certain portion of the research potential of Polish universities and Academy institutes, having been compiled from among projects submitted by only some directors of such research centers. We would like for this catalog to be further supplemented by all Polish universities and institutes that can boast such top-notch research results, which after adequate development or refinement may be successfully applied in practice. This systematically supplemented catalog will be presented at various seminars and meetings in the future, facilitating the more effective harnessing of research findings for practical applications.

Bogusław Smólski
Władysław Włosiński

The “Assistant for the Blind” – a set of mobile phone applications and audio functions for aiding the blind, elderly, and people with poor vision

■ OVERVIEW OF RESEARCH FINDINGS

The Assistant for the Blind is a package of programs working under the Symbian operating system on mobile phones (chiefly the Nokia 60 Series), wherein basic mobile phone functions are redesigned and adapted to suit the needs of the blind. The Assistant employs wizards that simplify and aid the use of complex programs known from the PC platform. The blind user gives oral instructions – a method for operating typical mobile phone functions and additional applications that is very simple and may be also very helpful for elderly individuals. All instructions in the programs, including filling in text in forms, are audio instructions. The Assistant encompasses the following applications, cooperating with a Polish speech synthesizer: Telephone (typical phone functions, a directory, phone calls, text messages), Calculator, Dictaphone, Agenda, Alarm Clock, Clock, Date and a simple Internet browser based on RSS channels.

Other commercial programs for using audio functions on mobile phones focus solely on screen communications. With our Assistant, the use of the phone by the blind takes place within an environment cre-

ated specifically for this purpose. Last year, telephones working under the Symbian operating system accounted for 70% of the market of intelligent mobile phones.

The final cost of the device (approx. EUR 250-500 depending on the mobile phone model; this price could be much lower for subscription phones) includes the cost of the application (approx. EUR 225) plus that of the speech synthesizer (approx. EUR 200). Distribution will follow a similar approach to the sale of computer applications. The software may be sold already installed on a phone (along with the phone).

The application operating on a Nokia 6600



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Method of producing nanocrystalline titanium dioxide in the form of a film

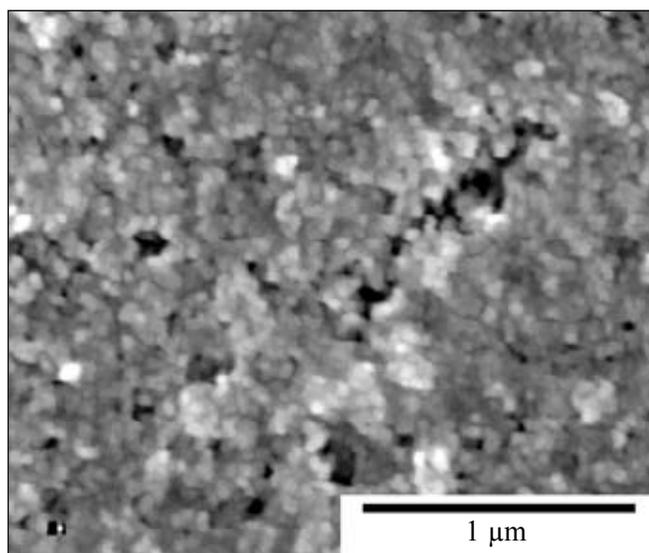
OVERVIEW OF RESEARCH FINDINGS

This method of producing nanocrystalline titanium dioxide (TiO_2) in the form of a film from alkoxy derivative of titanium involves turning an alkoxy derivative of titanium, preferably tetraisopropoxy titanium, into a complex with methacrylic acid in an inert gas atmosphere (argon) at room temperature in the course of 1 hour. The complex is subjected to hydrolysis and mineralization using a water solution of hydrogen peroxide in an air atmosphere at room temperature over 12 hours. The obtained precursor of titanium dioxide as oksotitanium nanoblocks undergoes crystallization in gel in the presence of a cellulose derivative (preferably hydroxypropyl cellulose) in a water or water-alcohol solution at a temperature of 90-120°C over 20 hours. The produced suspension of titanium dioxide nanoparticles in a crystallographic form of anatase in the solution of cellulose derivative is condensed and spread thinly by the coating method on a glass surface. After vaporizing the solvent in the air at room temperature, we obtain a transparent film of hybrid nanocomposite titanium dioxide-hydroxypropyl cellulose, which when heated in the air to a temperature of 450°C

over 45 minutes undergoes mineralization to a nanocrystalline titanium dioxide film, transparent to visible light, in the form of anatase with 25% w/w with the share of rutile. Hydroxypropyl cellulose is used in amounts of up to 10% w/w in relation to the mass of alkoxy derivative of titanium. The method leads to the production of a transparent mesoporous nanocrystalline film of titanium dioxide in the form of anatase, yet a temperature above 450°C is applied only at the last stage, i.e. during HPC thermal mineralization.

The final product of oksotitanium gel crystallization is the suspension of TiO_2 nanoparticles in water, which after condensation or centrifuging is turned into a paste. The production of TiO_2 nanoparticle paste and its use in the production of TiO_2 layers can be performed independently. The method enables TiO_2 layers to be produced on glass and steel surfaces of any size. Furthermore, the cost of producing a layer of 1 m² is much lower in comparison to popular methods of vacuum evaporation and requires only simple laboratory equipment rather than complex apparatus.

SEM image of a mesoporous nanocrystalline TiO_2 layer



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Method of concentrating wall field exploitation, particularly in the case of a longwall with caving

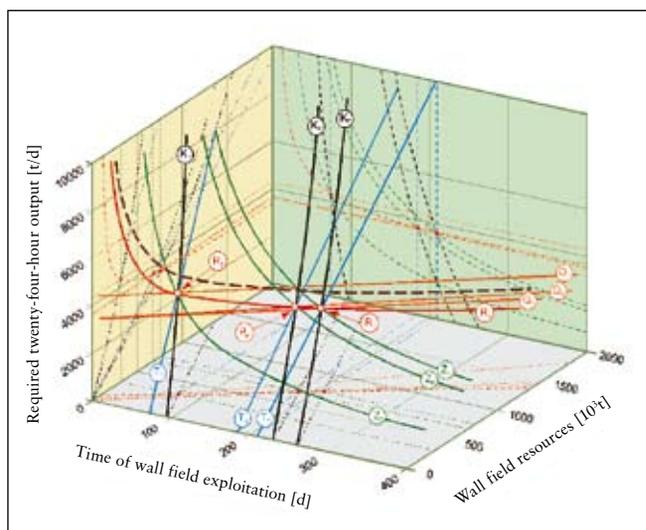
OVERVIEW OF RESEARCH FINDINGS

To date, the level of output concentration has been estimated by analyzing the production results of coal mining in Poland or trends in the world's mining. Our method takes a new approach to the problem of high concentration perceived as twenty-four-hour output, where a balance between the costs of coal extraction and revenues from coal sale is achieved, while taking account of the mining and geological conditions, technological and organizational circumstances, as well as economic and financial conditions pertaining to a given wall face. The method proposes a different approach to the wall face, factoring in the reaction of costs to the change in wall field exploitation time, while analyzing the costs of preparing the field for exploitation. Making allowances for the time factor has led to the establishment of three cost categories: absolutely fixed costs, relatively fixed costs and variable costs. As a result, the economic model developed enables the determination of the required twenty-four-hour output in relation

to wall field resources and wall field exploitation time for an assumed income level or balance between costs of coal extraction and revenues from its sale. In contrast to other methods, the 3D research space with viewing planes helps to determine the substitution of two variables indicating wall field resources and exploitation time when establishing the amount of twenty-four-hour output, while taking into consideration the cost structure and technical and organizational conditions as well as limitations related to exploiting a given wall face.

The proposed method has been covered by patent application No. P.381 762 submitted to the Patent Office of the Republic of Poland. Its authors were awarded a medal at the Economic and Scientific Innovation Fair INTERTARG 2007 and the Golden Medal in the field of mechanics and general engineering at the International Exhibition of Inventions IWIS in 2007.

An example of the relation between required twenty-four-hour output vs. wall field resources and the time of wall field exploitation



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Waste free utilization of asbestos and asbestos-containing materials

OVERVIEW OF RESEARCH FINDINGS

This technology employs an innovative process of waste digestion using phosphoric acid in a specially designed technological system which helps to obtain useful and safe products such as calcium and magnesium phosphates as well as easy to use silica.

In comparison to methods that rely on disposing waste in landfills, the technology is completely novel – it does not generate any wastes. Its originality is manifested in the fact that it uses a safe chemical agent, i.e. phosphoric acid, while the complete destruction of serpentine-type and amphibole-type asbestos takes place owing to an innovative reaction system. There is no equivalent technology in the world producing useful substances without generating another, possibly safe, waste. An average industrial installation has processing capacity of 300,000 tons of eternit (or another asbestos waste) per year. Utilization products include: TSP or MCP-type fertilizers – 106.000 t/y, silica – 7.200 t/y per 100% of SiO₂. A plant generates profits of approx. EUR 975 per ton of eternit (income from eternit dismantling and storage amounts to approx. EUR 175). The technology is also beneficial from an ecological and social perspective.



Asbestos waste – an example of improper waste handling

The technology is the subject of patent application No P-359958, 2003: Trefler B., Pawełczyk A., Zwoździak J., Institute of Inorganic Chemistry, Czarny A., “Method of waste free utilization of asbestos and asbestos containing materials.”

Eternit roofing – a source of air pollution



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Ultrasound Transmission Tomography (UTT) for examining the internal structure of media (particularly biological media, e.g. female breasts)

■ OVERVIEW OF RESEARCH FINDINGS

Our research station enables non-invasive in vitro imaging of the internal structure of biological media immersed in water and imaging of the internal structure of other objects. The major advantage of UTT lies in the opportunity to obtain images of internal structures by measuring a number of different acoustic parameters – such as the speed of ultrasound wave propagation, the damping coefficient, and the derivative of the frequency damping coefficient – which improves the efficiency of diagnosing, for example, pathological changes in tissues. Currently, the

research station enables the internal structure to be reconstructed by measuring the average speed of ultrasound wave propagation with a precision of approx. 0.04 m/s and by measuring the damping coefficient.

Other advantages include harmlessness, non-invasiveness, and an absence of ionic radiation. The device enables 3D imaging, both qualitative and quantitative characterization of tissue properties, and therefore can help distinguish between pathological changes of indolent and malignant nature (helping to reduce

View of a UTT station



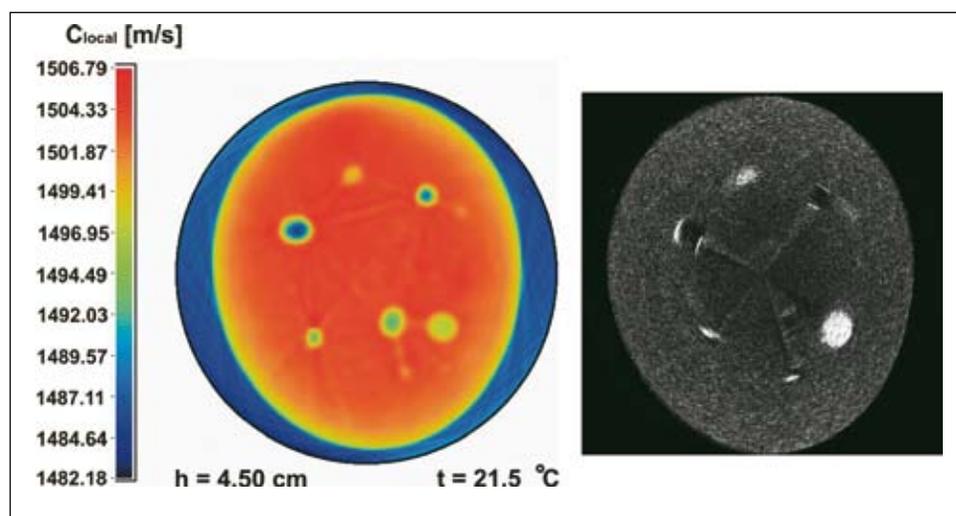
Biopsy phantom of the breast



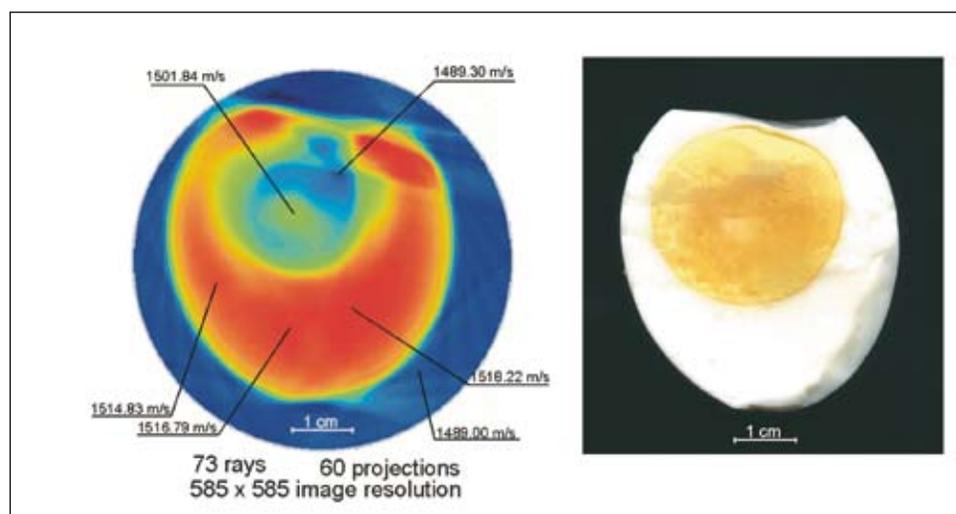
**Biopsy Phantom
 CIRS model 052**



Targets	Color	Size [mm]	Quantity	Position
cystic masses	green	8 – 15	6	random
dense masses	black	6 – 12	6	random
background	white	120:150:70		



Reconstructed images of breast phantom cross-section: a) reconstructed by the UTT method, b) USG image



Images of boiled hen's egg cross-sections: a) reconstructed by the UTT method, b) optical scan

invasive biopsy). Furthermore, the system makes it possible to image the dense breast tissue typical for young women and is available for frequent prophylactic checkups and monitoring treatment effectiveness. The image created by the system is in digital form (facilitating the possibility of computer-assisted diagnosis, telemedicine).

The device is covered by patent application No. 376854 submitted to the Patent Office of the Republic of Poland on 1 September 2005, entitled "Method of visualizing internal medium structure and a device for implementing this method."

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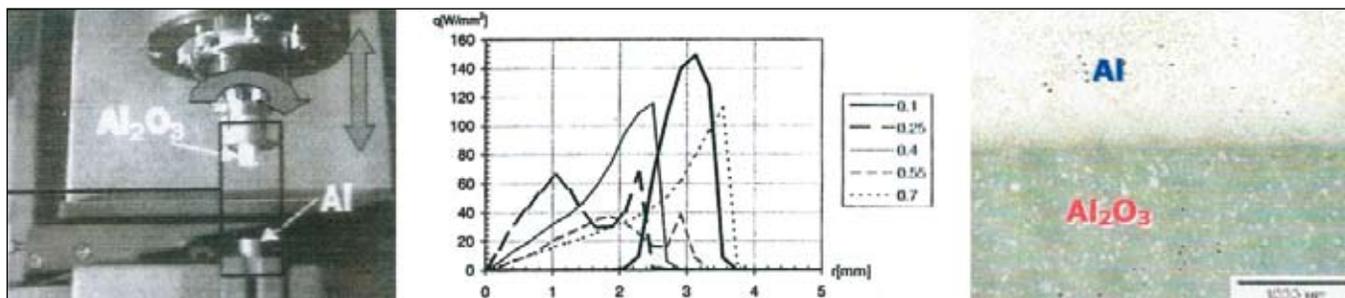


Technology for bonding elastic materials (ceramics of Al_2O_3 , AlN , SiC , Si_3N_4 , TiN types) with plastic materials (steels, intermetallics, composites) using friction

OVERVIEW OF RESEARCH FINDINGS

Selected conditions in the course of Al_2O_3 -Al bonding are as follows: rotation of 14500 rpm (revolutions per minute), friction time – 850 [ms], upsetting time – 3500 [ms], press-down pressure at the friction phase – 18 [MPa], press-down pressure at the upsetting phase – 46 [MPa], atmospheric air. The developed technology is a pioneering concept not only on a national scale. The technology helps to bond modern ceramic materials such as Al_2O_3 , SiC , Si_3N_4 , TiN with metals and metal alloys or to bond ceramic-metal composites (Al_2O_3 -Cr) and intermetallic

alloys (FeAl and NiAl type) with metals. Aside from being relatively cheap, it does not require specific protective atmospheres. In some cases (e.g. Al_2O_3 - Ni_3Al) the surfaces of bonded materials should be appropriately prepared. The technology can be used successfully in dielectric-conducting elements with a high heat absorption coefficient (microelectronics, lasers) as well as elements used at high temperatures and under corrosive conditions (FeAl-steel). The method is covered by a patent application.



a) adjustment of bonded elements, b) distribution of heat flux on the contact surface for the given timing of the process, c) structure of an Al_2O_3 -Al joint

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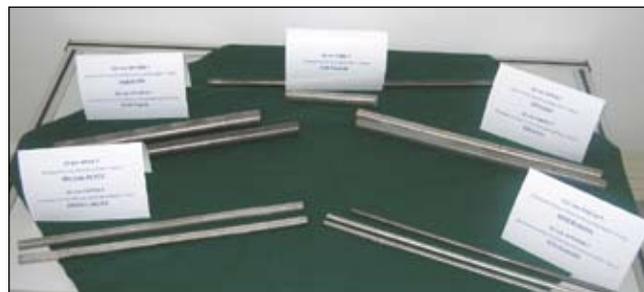
Practical implementation of tungsten heavy alloys (WHA) designed for special application

OVERVIEW OF RESEARCH FINDINGS

This product offers a strength range of 450-650, 600-700, 900-1100, 1500-1600, and over 1700 Mpa, density of 17.2-18.6 Mg/m³, diameter of 10, 14, 20, 28, plus other parameters as ordered. The product is comparable to articles manufactured by few companies in the world (2-3 production plants in the UE) and it is unique for 23 mm FAPDS projectiles.

The scale of production currently stands at 10 tons per year, with a possible production capacity of 25 tons per year; in the future it will increase to 80 tons per year. The methods of promotion include: cooperation with companies using the product for further manufacturing, presentation of the product at fairs,

and efforts to obtain funds for its development. The target group here is manufacturers in the defence industry. The estimated price of 1 kg of rods is approx. EUR 125 per kg, while the price of the processed product is approx. EUR 625 (using 1 kg of rods). The product is protected by 2 patents related to the technology of wolfram heavy alloys. The production technology has been developed in the course of a specific-purpose project, statutory and research activities commissioned by manufacturing plants.



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Removal of heavy metals from wastewater and galvanic sludge

OVERVIEW OF RESEARCH FINDINGS

This technology involves the use of microorganisms for the elimination of metals from wastewater and galvanic sludge. It has been shown that metals such as iron, zinc, copper, or chromium can be effectively removed from wastewater via a biosorption process by a biomass of microorganisms, such as activated sludge. The process of metal binding takes place very quickly – practically within several minutes, and its efficiency ranges from 45% to 99% depending on the type of metal and the wastewater composition. Metals accumulated in the biomass can then be recovered by microbiological leaching, with an efficiency of 70-90%.

Traditional technologies based on biohydrometallurgical methods use autotrophic bacteria oxidizing iron and/or sulfur. The proposed process for removing

metals from waste also uses heterotrophic microorganisms, which both oxidize sulfur (to produce sulfuric acid) and produce organic acids or complex compounds. An appropriate leaching culture composition to ensure optimum growing conditions for specific bacteria groups enables effective leaching of metals from such problematic waste as galvanic sludge.

This technology is an innovative solution. The amount of equipment applied depends on the amount of wastewater and sludge to be treated. The process requires a bioreactor suitable for the given technical and technological conditions.

The technology is designed for removing heavy metals from wastewater and sludge. It can be especially useful to small facilities, owing to the simplicity of the solutions applied and their easy operation.

Biosorption/bioleaching reactor



Metal bioleaching bacteria



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Method of synthesizing ferromagnetic nanoparticles via the pyrolysis of metal containing polymers

■ OVERVIEW OF RESEARCH FINDINGS

Ferromagnetic composites consisting of elementary metal, metal oxides, or carbide nanocrystallites stabilised in an inorganic matrix are obtained by a procedure including the formation of appropriate metal acrylate or acrylamide complexes, followed by frontal polymerization and pyrolysis of the polymer at various temperatures. The pyrolysis products take the form of powder particles of irregular shapes and sizes. These particles contain randomly distributed nanocrystallites having various composition and sizes ranging from a few nm to tens of nm (Fig.) depending on the type of the starting monomer and pyrolysis temperature. The application of this procedure stabilizes the nanostructure and enables the processing of spherical nanoparticles within a narrow window of sizes. The magnetic parameters can be tailored by altering the processing variables.

The materials may find potential application in targeted drug delivery.

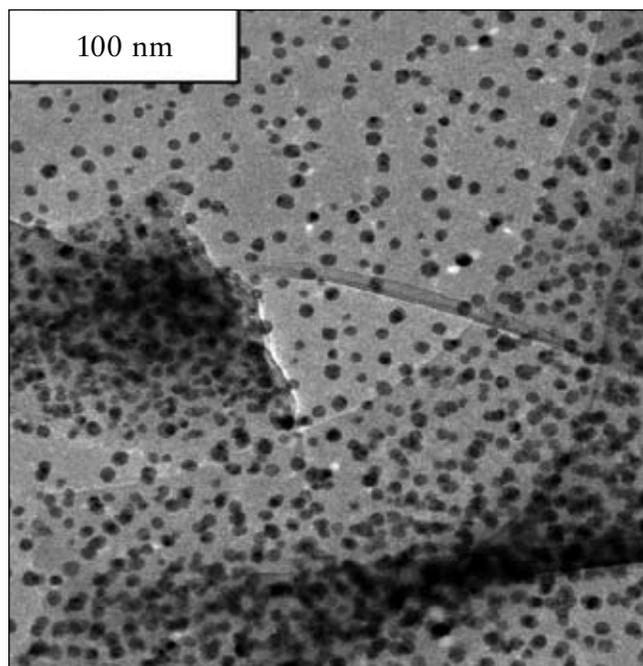


Fig. HRTEM micrograph of the ferromagnetic nanocomposite

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High-performance melt-spun Nd-Fe-B permanent magnet alloys for bonded magnets

OVERVIEW OF RESEARCH FINDINGS

Melt-spun ribbon alloys from the system $\text{Nd}_9\text{Fe}_{77-x}\text{B}_{14}\text{M}_x$ ($M=\text{Ti}, \text{Mn}, \text{Mo}$) have been developed. These alloys are fabricated by overquenching and annealing. Using an appropriate combination of material composition and processing parameters, materials may be produced with a uniform, nanocrystalline microstructure. Refractory additions change alloy morphology and phase constitutions leading to enhanced magnetic properties (Fig.).

A pulverised ribbon alloy can be used for polymer bonded magnets.

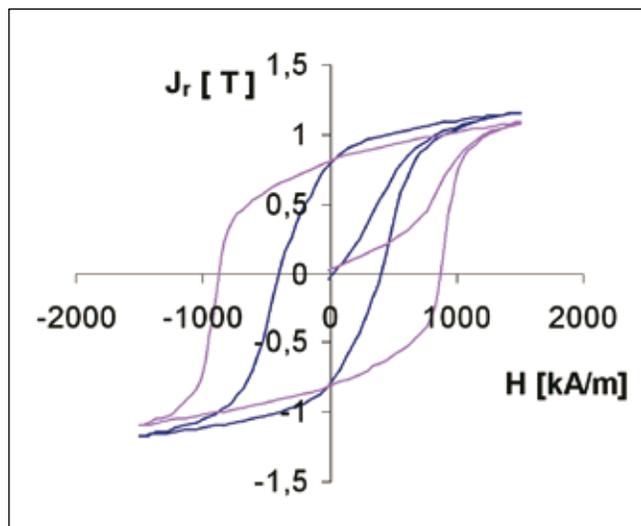


Fig. Hysteresis loops for the $\text{Nd}_9\text{Fe}_{77}\text{B}_{14}$ and $\text{Nd}_9\text{Fe}_{73}\text{B}_{14}\text{Ti}_4$ alloys

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The K9 piston aircraft engine

OVERVIEW OF RESEARCH FINDINGS

This is a piston engine developed on a M18/F basis with take-off power of $N=883\text{KW}$, time between failures – $T=1200\text{ h}$, full service life – 6200 h , operating time with take-off power – 15 min , fuel consumption for $0.9N_n$ – 270 g/KMh , and oil consumption for $0.9N_n$ – 8 g/KMh .

The engine dimensions are as in the case of the engine M18/F-KAF, while its weight amounts to 550 kg .

The engine was developed within the framework of the purpose specific project No. 6T082003C/06165 “Development and implementation of technology for laser hardening of materials from the alloys of aluminium and alloy steel in the production of aircraft piston engine elements” (2003-2006) conducted by WSK “PZL-Kalisz” S.A.-PW. The supervisor of the project was W. Ostapski.

The planned scale of production amounts to 100 items per year (WSK “PZL-Kalisz” S.A.) and the estimated price of the engine is USD $99\ 000$.



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The M18/F-KAF piston aircraft engine

OVERVIEW OF RESEARCH FINDINGS

This prototype piston aircraft engine was developed on the basis of the ASz-62IR engine, with take-off power of $N=770$ KW, time between failures increased to 1550h, fuel consumption reduced to 270 [g/KMh] and oil consumption reduced to 8 [g/KMh], increased mechanical efficiency, vibration level reduced by 30%, exhaust gas emission reduced to do HC -70ppm, CO_2 -2%. The engine weighs 540 kg and its dimensions are as in the ASZ-62IR engine.

The engine was developed within the framework of the purpose specific project No. 6 T081542001C/5673 “The implementation of the technology to produce composite diffusion wear-resistant layers in the production of aircraft engine elements” (2003-2006) conducted by WSK “PZL – Kalisz” S.A.-PW. The supervisor of the project was W. Ostapski.

The engine has been sold by WSK “PZL – Kalisz” S.A. since 2006, with its annual production rate at approx. 100 engines. It costs USD 70 000. The engine is easy and cheap to operate. It is designed for agricultural aircraft and fire-fighting aircraft such as the Dromader.



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Tailor-made nanostructures in light metals

OVERVIEW OF RESEARCH FINDINGS

Despite more and more frequent application of composites, metals and alloys remain the prime materials for structural parts. This is partly due to efforts to improve their mechanical properties (i.e. tensile strength, fracture toughness and fatigue). However, the possibilities for improving material properties by conventional methods of alloying and heat treatment appear to be limited. Consequently, grain size refinement to a nanometer scale is one of the most promising routes for improving mechanical properties – under the well-known Hall-Petch relationship, one can expect a substantial increase in mechanical strength when the grain size is reduced below 100 nm.

Fig. 1. Microstructure of 2017 aluminium alloy (a) and titanium (b) processed by hydrostatic extrusion

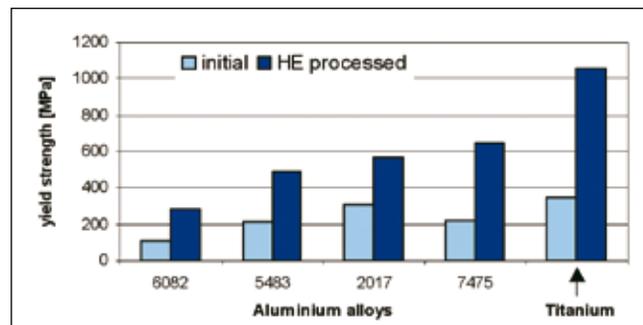
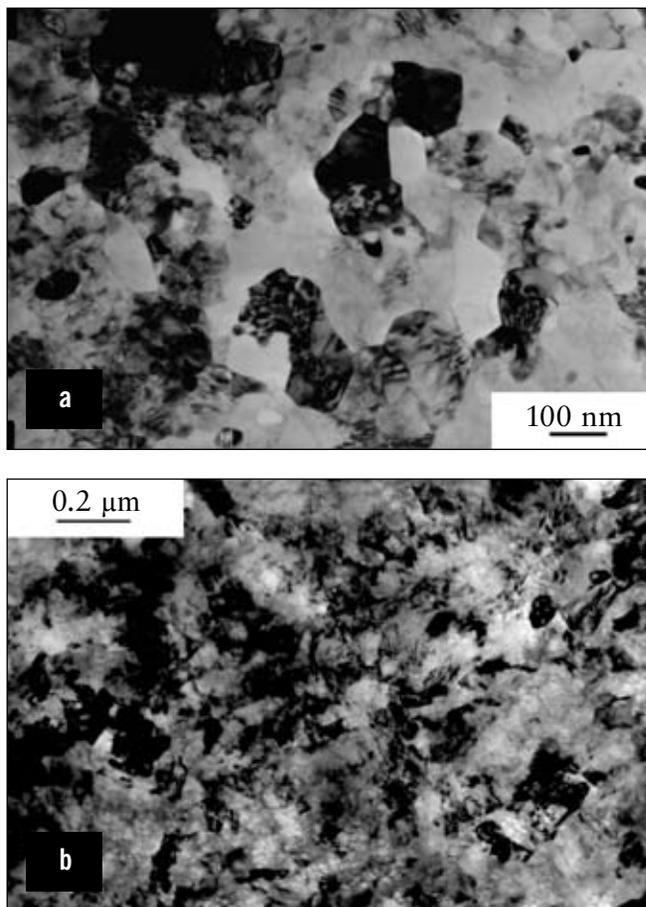


Fig. 2.

There are a number of methods resulting in grain size refinement in metals. However, there are some limitations in this respect stemming primarily from the lack of efficient techniques for large-scale and cost-effective production. One of the possible solutions here is the modification of existing SPD techniques or the development of new methods. In this context, hydrostatic extrusion has been shown to be an alternative way of grain size reduction to a nanometer scale and has been successfully applied in the case of various materials (see Fig. 1). Hydrostatically extruded materials show very high strength (Fig. 2) which cannot be achieved using conventional material fabrication techniques.

The most important characteristic of hydrostatic extrusion in terms of its application is the possibility for obtaining relatively large dimensions of processed materials in the form of rods, wires, and tubes. Such semi-products can be easily employed in industrial production, for example in the manufacturing of medical devices and implants.

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Preventing industrial failures

■ OVERVIEW OF RESEARCH FINDINGS

Industrial equipment is often exposed to a harsh environment involving high/low temperatures and pressure, high concentration of process gases such as vapour or hydrogen, and corrosive media. Such operating conditions can lead to accelerated structural degradation of materials resulting in their lower ability to withstand various loads and, consequently, provoking component failure. Therefore, monitoring and reduction of the degradation of structural materials is an effective method for preventing industrial failures.

The holistic approach to monitoring the degradation of industrial installations and components adopted by our Faculty involves: (1) the collection and analysis of background data, (2) design check using the finite element method (Fig. 1), (3) non-destructive examinations using various methods (Fig. 2 and Fig. 3), (4) destructive testing such as mechanical tests (including minimally invasive methods – Fig. 4) and microstructural investigations (Fig. 5) and (5) the assessment of remnant component service lifetime.

Non-Destructive Testing (NDT) is meant to assess the structural integrity of a component and to identify structural defects and their location. Applied NDT techniques include: (1) acoustic emission, (2) ultrasonic testing, (3) eddy current defectoscopy, (4) dye penetrant testing, and (5) visual testing.



Fig. 1. Stress distribution in the upper part of a catalyst regenerator

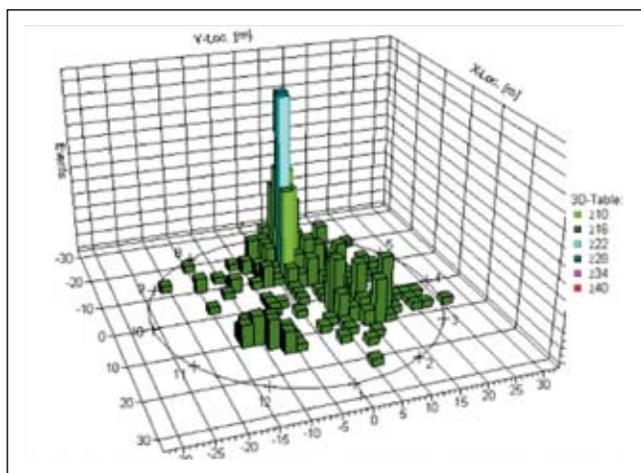


Fig. 2. Location of the intensity of AE sources on the floor of a 50,000 m³ storage tank

Fig. 3. A multi-channel system for acoustic emission signal acquisition and analysis – Valen AMSY5



The characterization of materials microstructure is performed using state-of-the-art equipment (Fig. 6) and provides a description of the examined materials on the nano-, micro- and macro-scale. The techniques used here include: (1) Transmission Electron Microscopy, (2) Scanning Electron Microscopy, (3) Atomic Force Microscopy, (4) X-ray diffraction phase analysis, and (5) Metallography (also an on-site variant).



Fig. 5. HR-SEM image of sulfides in structural steel



Fig. 4. Miniaturized samples for tensile tests

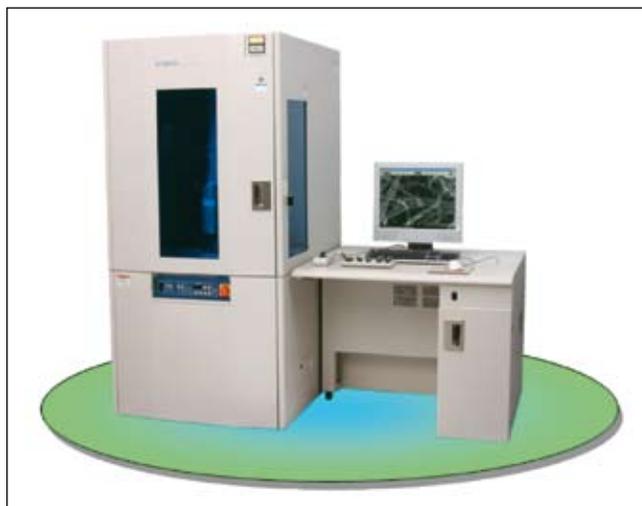


Fig. 6. High Resolution STEM, HITACHI S-5500; resolution at 30kV – 0.4 nm

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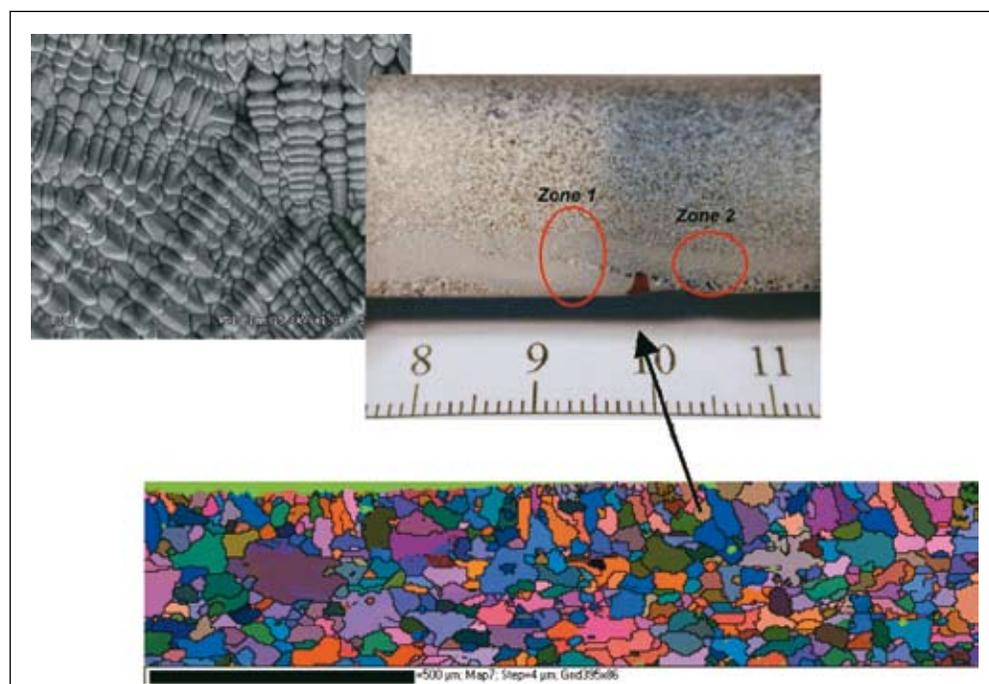
Precision casting of aircraft engine elements from nickel alloys

OVERVIEW OF RESEARCH FINDINGS

The Faculty of Materials Science and Engineering (FMSE) of the Warsaw University of Technology is a leading research institution in the field of materials science in Poland. The FMSE works in close cooperation with the Polish aerospace industry, especially in the field of developing new casting technologies. Scientific and technological know-how plus the Faculty's experience in investment casting guarantee a high caliber of research and a flexible approach to customer-tailored and problem-oriented solutions.

Investment casting of critical elements for aircraft engines is a complex process, which may lead to

various defects occurring in castings. The problem of surface defects is especially important in the case of long-run industrial production of castings for aircraft parts such as blades, gas flow guide segments, guide apparatuses for turbines, and casings. These elements are of primary significance for flight safety and must not have surface defects even as minor as a few hundredths of a millimeter. The scholars at the FMSE have developed production technology guidelines for precision castings of aircraft engine elements from nickel alloys, minimizing the share of defective products.



Microstructure of a cast

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A group of autonomic mobile robots cooperating to perform transportation tasks

■ OVERVIEW OF RESEARCH FINDINGS

These 2-wheel mobile robots use a wireless data transmission technology. They are equipped with ultrasonic, infrared and photo-optic sensors. Their parameters are as follows: length – 400 mm, width – 300 mm, height – 300 mm, and weight – 5 kg.

The robots may be applied in factories for organizing the transportation of products. Furthermore, they can serve educational purposes; the robots may use advanced algorithms for controlling a single unit or a group of units.



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Parallel robot with three degrees of freedom for high-speed milling

■ OVERVIEW OF RESEARCH FINDINGS

This 3-degrees-of-freedom robot may be applied for milling 3D elements made of aluminium, wood, stone, etc. It is characterized by fast idle movements and high rigidity.

Operating space parameters: diameter – approx. 0.3 m; height – 0.3 m; spindle power – 1.4 kW. Maximum rotations – 42 thousand per minute; maximum mill diameter – 8 mm; average cutting force – 80 N. Maximum dimensions: diameter – 2.6 m and height – approx. 2 m; weight – approx. 600 kg.

The robot is covered by the following patent applications: P-363255, P-363254, P-377752.



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Round wire rod made of highly-advanced aluminium alloys for AAAC, AI59, HTLS, EHC type wires

■ OVERVIEW OF RESEARCH FINDINGS

These wire rods are made of aluminium AlMgSi, AlCuFe, AlZr alloys. Their tensile strength ranges from 100 MPa to 200 MPa, their resistivity from $28.2\text{n}\Omega\text{m}$ to $34.0\text{n}\Omega\text{m}$. They are produced in the dimensions 7.5-12 mm.

The production scale of the type series of alloy rod wires is 6000 tons per year. Promotion and sales of the product are being handled by the NPA Skawina Sales and Marketing Department. Furthermore, the technology is being promoted at conferences and information about the research result is published in specialist journals. Developed by the Faculty of Non-Ferrous Metals (AGH University of Science and Technology) within the framework of a targeted project financed by the Committee of Scientific Research, this wire rod production technology is slated to be patented.



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Design, testing and application of ferrofluidic seals (FFS)

■ OVERVIEW OF RESEARCH FINDINGS

The concept of ferrofluidic seals relies upon specific magnetic properties of ferrofluids in a magnetic field. A ferrofluid injected into the area of a concentrated magnetic field forms a sealing barrier of exceptional efficiency. This contactless seal is characterized by absolute tightness (no leaks) and very low motion resistance.

Ferrofluidic seals may be used in rather low pressure conditions – up to approx. 0.5 MPa – both as static and dynamic seals. They are efficient especially under vacuum conditions (e.g. vacuum bushings in rotary shafts) and at high rotation rates. The Department of Machine Design and Terotechnology (AGH University of Science and Technology) has developed two unique stations, which help to identify the characteristics of rotary shaft ferrofluidic seals, particularly burst pressure and motion resistance. Notably, they have been used to investigate multi-stage seals and determine burst pressure against the number of stages, sealing gap height, magnetic field intensity and shaft rotations of up to 9000 rpm.

Ferrofluidic seals may be applied as static and dynamic seals. They can be particularly useful under

vacuum conditions (vacuum bushings in rotary shafts) and at/or at high rotation rates. The results of laboratory research and design solutions have been published in many national and foreign publications. They are protected under 30 Polish patents.



Station for testing tightness and tribological characteristics of ferrofluidic seals

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Technologies and industrial installations for applying layers and multi-layer structures using PVD (physical vapor deposition) methods

■ OVERVIEW OF RESEARCH FINDINGS

This technological offer involves the implementation of research findings and physical methods of applying layers and multi-layer structures (PVD) on large glass, ceramic, and metal surfaces or synthetic materials. These coats may be employed in industries related to building materials, electrical machinery, electronics, and aircraft construction, or for the production of emergency equipment for fire services and other rescue units. The technologies offered are based mainly on magnetron sputtering and arc plating. The researchers at the Department of Electronics have significant experience in implementing industrial installations using these technologies.

The technologies and industrial installations offered are designed for applying metal, metal oxide, nitride, and other layers and multi-layer structures. These are mainly coats such as reflecting mirrors, half-permeable mirrors (for the light), coats permeable for optic radiation and reflecting infrared radiation, and light-permeable conductive (heating) coats (glass panes used in aircraft or railway transportation services, and military equipment). Other proposed technologies are used for applying anti-reflection coats, which reduce light reflection from the glass surface and, as a result, increase its permeability.

Furthermore, the technological offer encompasses installations for coating three-dimensional elements made of glass, ceramic, metal, and synthetic materials with decorative layers increasing their resistance to corrosion factors. The technologies based on ion magnetron sputtering and arc plating help to apply so-called hard coats on tools for machining processing or machinery parts, prolonging their operation time.

The market demand for metallized foils from synthetic materials or fabrics from synthetic fibers is growing. The proposed ion magnetron sputtering is a method used by such companies as Applied Films, Leybold, Gwardian, etc. Recently, arc plating has been promoted mostly owing to the possibility of applying “hard” coats from titanium nitrides and titanium carbon nitrides or other metallic coats and their compounds.

A major advantage of these technologies is that they have been developed and are implemented by Polish scientific centers and enterprises; the possible launching of production would serve to boost their staff employment.

The technology is prototypical and patented. A possible agreement could be concluded in the form of a mandate agreement or a purpose specific project.

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Mortars for repair work in the renovation of historical stone objects

OVERVIEW OF RESEARCH FINDINGS

Stone conservation represents an important element of renovation work to restore the past appearance of historical stone objects. Our mortar masses can be used in the conservation and reconstruction of different sandstone and limestone varieties, enabling:

- detailed reconstruction of structures made of sandstones and limestone, renovated through the appropriate choice grain size,
- causing harmful substances to migrate and to accumulate in the conservation masses due to their larger porosity and water absorption,
- achieving stable conservation by applying reconstruction masses with lower compression strength than that of the stone being restored.

These mineral masses are characterized by the following properties:

- low shrinkage after 28 days (0.03-0.12 mm/m)

increasing to 0.2-0.3 mm/m and stabilized after 90 days; full frost resistivity,

- low capillary rise and, simultaneously, slow evaporation of water from wet masses,
- very high resistance to crystallization pressure of water-soluble salts,
- applicability under normal atmospheric conditions,
- fresh masses display very good working properties such as plasticity, workability, coatability/spreadability, and retain these properties well over time.

The masses may also be used to produce architectural details, small stone artifacts, casts, tombstones, and statues as well as prefabricated, decorative concretes and concrete sculptures.

The mineral masses represent an original Polish product and are protected by patents P-331977 and P-331980.

St Mary's Church in Kraków



The Zygmunt Chapel of the Royal Cathedral (Wawel)



TECHNICAL SCIENCES – POLISH UNIVERSITIES**Awards:**

- The Polish Prime Minister's Award for outstanding domestic scientific and technical achievements, Warsaw, 2000
- Grand Prix in the „Product” category, 2nd International Fair „Geology 2004”, Warsaw, 2004
- Nomination in the Allianz Awards competition, Kraków, 2004



The coat-of-arms of the Boner family – a mineral mass of medium-grained Pińczów limestone was used in its reconstruction



Surface of a shield featuring the coat-of-arms of the Boner family from 1516, carved by Santi Gucci (St Mary's Church in Kraków), after being cleaned during conservation work – made of Pińczów limestone, the shield had become highly decomposed

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Middle and long wavelength photodetectors operating without cryocooling

OVERVIEW OF RESEARCH FINDINGS

The importance of sensitive and fast detection of long wavelength IR radiation without cooling was recognized in Poland in the early 1960s and became a primary subject of interest on the part of many Polish scientists, who proposed numerous concepts and practical solutions related to uncooled detection. In the early 1980s, the company VIGO System S.A. was founded to develop and commercialize uncooled IR detectors.

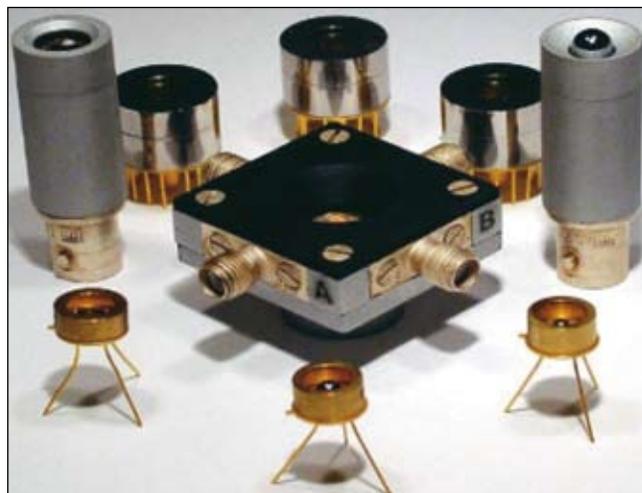
VIGO System S.A. has developed unique technologies for MWIR and LWIR photodetectors oper-

ating without cryocooling. These devices are optimized for operation at any wavelength within a wide spectral range (2-16 μm). They are characterized by high sensitivity, close to the fundamental limits set by the quantum noise of thermal radiation generated by the 300K background. Simultaneously, the devices show very fast response (100 picosecond). These results were obtained through intensive research in the field of optoelectronics, especially in the field of physics and technology of narrow gap semiconductors.

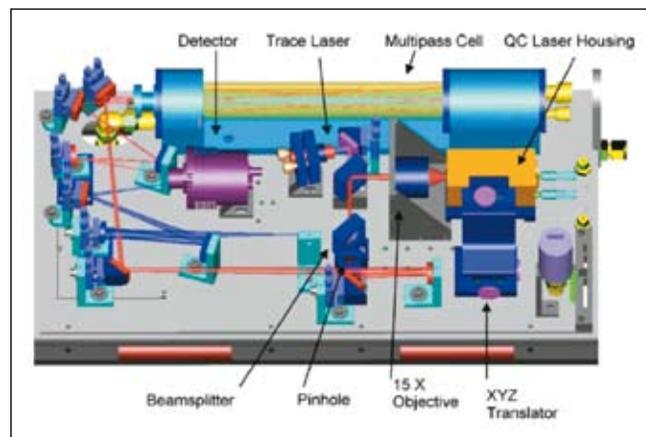
Advanced MOCVD system for HgCdTe growth



HgCdTe photodetectors manufactured at VIGO System S.A.



Ultrasensitive gas analyzer with PVI-2Te VIGO photodetectors





Laser threat warning system for tank crew with uncooled MCT photodetectors



NASA 2009 Mars Science Laboratory Mission. Vigo delivered PVI devices for remote chemical analysis systems



Arm and hand image taken with the V-50 thermal imager, manufactured by Vigo

Vigo System S.A. proposed and implemented a new concept of photodetector, as a monolithic chip integrating optical, photoelectrical, and charge collection processes, processes involving signal processing, and the suppression of noisy thermal generation and recombination. A large variety of infrared detectors are now manufactured and exported to many countries around the world.

The sophisticated architectures of the devices are based on $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ multilayer heterostructures developed using the MOCVD growth technique. The present production scale is approx. 10,000 pieces per year and it is increasing rapidly. The facility has the potential to produce more devices of this type. In addition to photodetectors, the company develops and manufactures various detection modules including detectors, optical elements, temperature controllers, preamplifiers, and other signal processing electronics. The other products are complete IR systems such as thermographic cameras.

The photodetectors and other optoelectronic components have found important applications in numerous civilian and military infrared systems. They are used in IR metrology, ultrafast pyrometry, conventional, laser and Fourier spectrophotometry, laser technology, non-destructive material testing, second-generation freespace optical communication, ultrasensitive chemical sensing (ppm, ppb and ppt range), advanced medical diagnostics, in military applications (guidance, homing, range finders, alerters) and in aviation and space applications.

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High-strength polymeric materials obtained by constrained rolling

OVERVIEW OF RESEARCH FINDINGS

This method is characterized by:

- Highly oriented construction rods with high cross-section and without cavitation pores,
- High strength of approximately 350 MPa for polypropylene and polyethylene, 400 MPa for polyformaldehyde and polyamide in comparison to low-carbon steel products (220-400 MPa),
- High strength of the material in relation to its density.

Another advantage is a dramatic increase in the impact strength of oriented rods as compared to unoriented polymers. For example, the impact strength of polyethylene increases 20 times and the rods do not crack (they only delaminate), while for polypropylene the increase is 30-50 times. Polyamide 6 and polymethylene oxide react in the same manner.

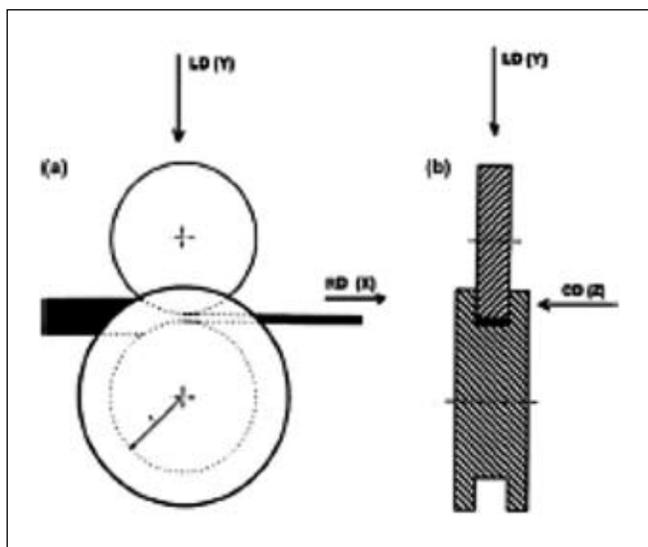
The method of polymer rod rolling is an innovative technology not yet applied in industry. Similarly, such rods are not used in practice. However, they can serve as rope cores (for lifts, elevators, oil and gas wells, fishing nets, etc.) taking the place of cores made of steel, synthetic or natural fibres. Aside from

their strength – similar to that of low-carbon steel – the major advantage of monolithic cores made of synthetic rods is the homogeneous distribution of stresses in the rope cross-section while the rope is bent and the elimination of the irregularities which accumulate during frequent reeling and unreeling of rope.

This method entails a lower cost of production as compared to metallic products of similar dimensions and strength. One of several advantages of applying these research results in practice is replacing steel with a cheaper polymer material with the same cross-section. Steel is approximately 8 times heavier than most plastics. While the price of polymer materials is approximately EUR 1 per kg and the price of steel rods is around EUR 0.5 per kg, it is estimated that the replacement of steel with polymeric rods could save EUR 0.25-0.5 per 1 kg of applied steel.

It is expected that further work in this respect will develop solutions which could be implemented by large-scale innovative enterprises interested in applying new technologies, which have the relevant R&D centres and educated staff.

The model of constrained rolling

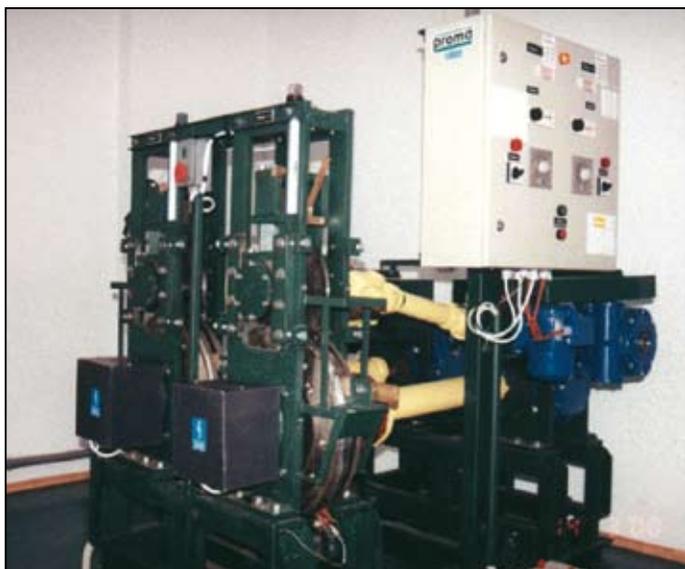


High-strength polymeric rods from various polymers with various cross-sections



We intend to publish the results of our work in professional journals as well as to promote the idea of replacing steel with high-strength profiles from plastics by establishing cooperative relationships with companies interested in our work. We expect that their marketing departments could help us to ac-

tively promote these new products. The Centre of Molecular and Macromolecular Studies is the owner of Polish Patent 178058 (2000) “Method and equipment for the production of highly-oriented rods and shapes from polymeric materials.”



- **4- rolls setup**
- **roll diameter - 280mm**
- **rolling speed up to 0.5 m/min (optionally to 4.2 m/min)**
- **temperature and speed of both sets of rolls controlled separately**

Apparatus for constrained rolling composed of two pairs of rolls, with rolling speed and temperature controlled independently

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A new control apparatus for independent lung ventilation

■ OVERVIEW OF RESEARCH FINDINGS

The idea behind the project was to develop a new kind of a control apparatus which, once connected to any type of ventilator, could enlarge its scope of application – from conventional ventilation of both lungs, independent, separate ventilation of each lung, to the ventilation of two patients by means of only one ventilator. Single lung pathology, or other causes of differing lung mechanics (like a car accident) leading to perfusion/ventilation mismatching, require subtle, precise control and monitoring of each lung ventilation and pressure generated during ventilatory treatment. These requirements are met by the new medical apparatus developed under the Eureka project No. E!3126 (2004-2005), as this device integrates a feedback-controlled divider of ventilation between lung tidal volumes and a pressure monitoring system for each lung.

Typically, ILV requires the use of two synchronizable ventilators permitting the selection of different ventilation modes and the application of selective positive end-expiratory pressure (PEEP). Synchronization is mandatory (particularly when using a respiratory rate $< 30/\text{min}$) in order to avoid mediastinum shift, which in turn may impede venous return

to the heart and decrease cardiac output. Furthermore, a non-synchronous inflation of the lungs may cause a number of ventilatory disorders. The major significant disadvantage of using synchronized ILV, as compared to conventional ventilation, is its double cost (2 ventilators with a synchronizing cable) and much more space needed for necessary equipment to be installed around the patient. Inspiratory and expiratory valves of these ventilators (immersed in inspiratory and expiratory ports respectively) open and close in a sequence, according to adjusted inspiratory, pause, and expiratory periods. This enables the creation of two independent parallel ventilatory circuits (one for each lung) connecting the inspiratory and expiratory ports of one ventilator to a double-lumen endotracheal tube to perform separate ventilation of the lungs.

The scale of production of the device depends on the interest shown by anaesthesiologists in its applications. Presently, the apparatus is undergoing clinical research in Poland.

The apparatus is protected by patent No. PI79784 (6 February 2001) entitled “System for selective lung ventilation.”



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A new unique shape of endotracheal tube

■ OVERVIEW OF RESEARCH FINDINGS

This endotracheal tube of a new unique shape reduces breathing resistances in the course of artificial lung ventilation and prevents vocal fold trauma.

The new endotracheal tube has a distinct geometry: the tracheal-laryngeal part is connected to the oral part by means of the lateral surface of a truncated cone. The area section of the tracheal-laryngeal part corresponds to the area section of the standard (cylindrical) tube, and the area section of the oral part is several times larger.

The cone-shaped tube shows considerably smaller gas flow resistance than the standard (cylindrical) tube, and smaller or comparable gas flow resistance in comparison to the resistance of the Cole (shouldered) tube of the same size. An important feature of the new tube is that its use reduces the work of breathing compared to the work measured using the standard tube.

A very important advantage of this tube is the considerably smaller risk of trauma in the area of the larynx (due to its geometry), during and after intubation, as compared to intubation with the Cole tube. The risk of trauma during intubation using the new cone-shaped tube seems to be similar to the intubation with the standard tube.

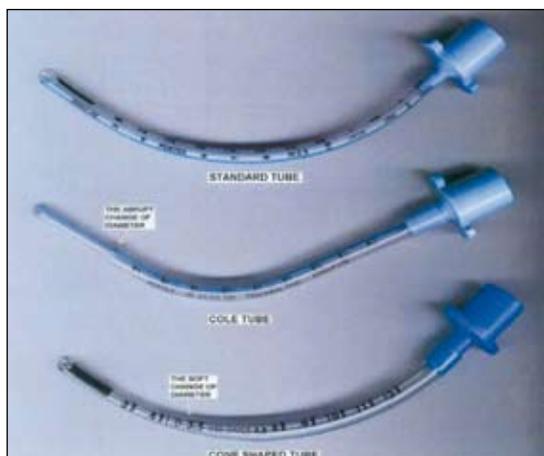
Further advantages resulting from the application of the cone-shaped tube are as follows: reduced barotrauma risk and a smaller risk of excessive increase of internal, positive end-expiratory pressure (auto PEEP) in the airways due to smaller tube resistance, and lower energy cost of breathing in comparison to the intubation by means of either standard or Cole tubes.

The aforementioned advantages are very significant from the clinical point of view, especially in the case of pediatric patients with respiratory failure with maintained but inadequate spontaneous breathing and in patients prepared for extubation.

The device has been developed under the framework of project no. 3T11E02830 (2006-2008) entitled “Optimization and clinical verification of respiratory parameters of the intubation model in long aided respiratory therapy.”

The device is protected by patent application No. P375669 submitted on 10 June 2005, entitled “Endotracheal tube.”

Plans call for the product to be put into mass production; its price will depend on the interest on the part of anaesthesiologists. Presently, it is in the course of clinical research.



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Time-resolved optical tomograph for the assessment of brain tissue oxygenation and perfusion

■ OVERVIEW OF RESEARCH FINDINGS

This prototypical device for assessing brain oxygenation and perfusion with the use of near-infrared spectroscopy is equipped with picosecond laser diodes, optomechanical switches enabling the switch of the light source position on the head surface, a set of fast photomultipliers to detect the radiation remitted from the examined tissue, and 8-channel system for time correlated single photon counting. The laser radiation reaches the examined tissue via 18 optical fibres, and the remitted radiation is transmitted via 8 fibre bundles. This is one of the most extensive devices of its type in the world, enabling simultaneous examination of both hemispheres and providing

4x4 oxygenation/perfusion maps of cerebral cortex oxygenation/perfusion.

Dimensions – 60 x 60 x 150 cm; weight – approximately 100 kg.

The device may be used for initial assessment of brain tissue perfusion, particularly in cases of severe cerebral stroke. The device is presently under scientific investigation, its parameters being optimized and its clinical use being verified. This includes comparative evaluation of the results obtained during the assessment of brain perfusion by optical tomography, SPECT, or MRI methods.



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Saccadometer – a device for early diagnostics of central and peripheral nervous system diseases

■ OVERVIEW OF RESEARCH FINDINGS

This device measures eye movement by measuring the light reflected from the corneal bulge (direct infrared oculography). Eye movement is stimulated by 4 miniature green and red laser projectors. It is possible to select one out of 12 diagnostic experiments. The results are stored in internal memory and are transferred to computer via optic-fibre cable and USB. The device is battery-powered (2 x AA, 1.5 V), it ensures complete optical isolation of the examined person from the computer recording the results, and enables full automatic regulation of measurement parameters. The Saccadometer is ready to carry out measurements as soon as it is positioned on the examined person's head.

The Saccadometer system constitutes a combination of a unique method of eye movement measure-

ment and a stimulator of saccadic reactions. It applies advances in optoelectronics, microprocessing technology, and automatic signal analyzing methods. It is the first integrated diagnostic system for assessing saccadic refixation reactions, which is palm-sized and simultaneously offers such high quality eye movement measurements.

Weight: the detector – 95 g, the controller – 115 g. Dimensions: the detector – 10 x 6 x 2.5 cm, the controller – 11 x 6.5 x 2 cm.

The Saccadometer is a basic element of the Brain-Watch system, meant is to monitor the activity of the central nervous system over the course of its physiological aging. The Brain-Watch system is designed also for detecting neurodegenerative diseases at their earliest, pre-symptomatic stage. The system may be used by individual persons, for instance by those endangered with the Huntington's or Alzheimer's disease. The measurement system is based on the patented eye movement sensor in the Cyclop configuration (Bertec Inc., Columbus, USA). It seems that complete implementation of Brain-Watch will trigger demand for devices of this type, possibly similar to the demand for devices used in automatic blood pressure measurement. Expected price: EUR 4000.



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The “Kajetek MMC” braille notebook

■ OVERVIEW OF RESEARCH FINDINGS

Providing speech synthesis for the rehabilitation of the blind, Kajetek is a unique speaking notebook for blind individuals. The speech it generates is characterized by very high clearness. Another specific feature of the device is its small size: Kajetek is one of the smallest speaking notebooks in the world, and the only one which is wholly Polish.

Aside from note-taking and browsing functions, Kajetek is equipped with a clock, calendar, diary,



stopwatch and timer, and optionally a GPS system. It can also function as a speech synthesizer. Owing to its very simple data transmission programs and a built-in MultiMedia Card reader, exporting text from computer to Kajetek is a very easy process. The device is also used as a speaking book, which can be “read” during a bus or tram journey. Using a memory card turns Kajetek into a small library which can be carried around.

The notebook won the “Butterfly 2001” award granted by the Main Council of the “Communication without Barriers” Foundation.

It is a microphonemic Polish speech synthesizer with dimensions of 17 x 7.7 x 3.5, weight of 220 g, and MMC external memory.

It is easy to operate and fast to respond; its synthetic speech is clear and well received by blind individuals.

The anticipated scale of production is approximately 100-150 items a year. Presentations and advertisements will be published in specialist journals. The price – EUR 750.

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Installation for flue gas desulfurization based on the wet limestone method

■ OVERVIEW OF RESEARCH FINDINGS

This flue gas desulfurization installation has a throughput of 20 000 – 400 000 Nm³/h and a SO₂ removal efficiency of > 95%. It is characterized by a (CaCO₃) sorbent usage of 1.7 kg/kg SO₂ and a maximum concentration of SO₂ in inlet gases of 5 000 ppm.

The size of the installation depends on the flue gas flow rate. Its characteristic feature is a two-step flue gas desulfurization process taking place in two spray towers with independent cycles of the absorbing suspension. The installation is also characterized by varying gas velocity and pH of the absorbing suspension. SO₂ may be removed using solid waste.

The scale of production will depend on a portfolio of orders, so far only individual installations have been implemented; licensing and/or turnkey arrange-

ments are possible. The installation was presented during the Poznań International Fair and the Katowice Fair of Environmental Protection. An offer for implementing the installation was submitted to the Science & Technology Park “Technopark Gliwice” Sp. z o.o. The technology is patented under patent No. PL 178199 “Flue desulfurization based on the wet limestone method.”

The advantages of the installation are as follows: high efficiency of flue gas desulfurization; almost complete sorbent utilization; flexibility of operation independent of variable parameters of flue gas flow and SO₂ concentration; simple and efficient operation; reliability of operation and low vulnerability to operational errors and oversights.

Installation for flue gas desulfurization at the heating plant ZACH Metalchem in Opole



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Implementation: Manfred Jaschik



Decision support system for regional-scale air quality management

OVERVIEW OF RESEARCH FINDINGS

The main module of the system is a regional-scale forecasting model of air pollution transport. The present implementation is sulfur-oriented and utilizes a multi-layer, two-component model designed for analyzing SO_x dispersion. It can generate short- or long-term forecasts of sulfur oxides concentration as well as distribution maps of cumulated, annual sulfur deposition.

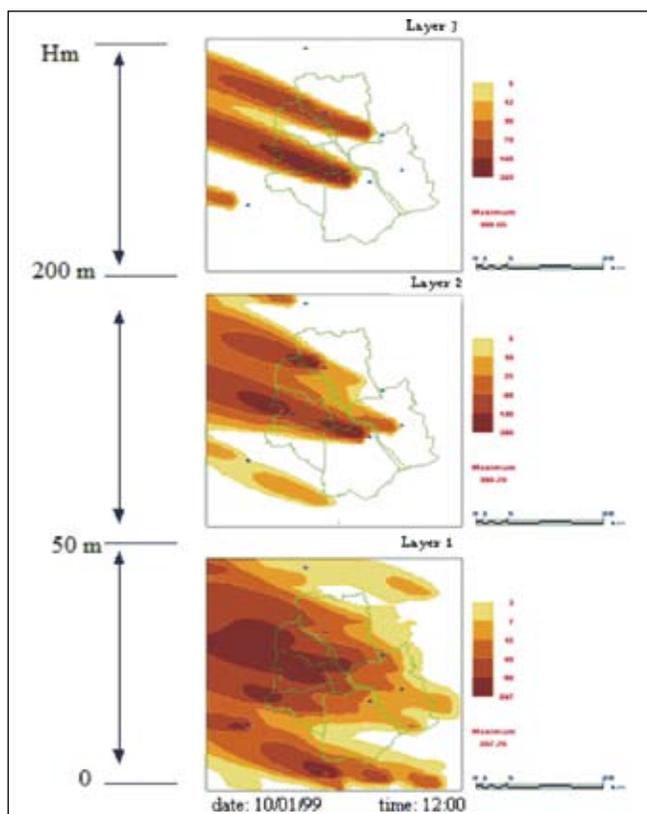
The main input data are a meteorological forecast and an emission field description, including point-wise and area spatial characteristics of emission sources. Concentration maps in consecutive time intervals are computed along wind trajectories, taking into account basic meteorological parameters. The results are generated in the form of primary (SO_2) and secondary (SO_4^-) pollutant concentrations

or as the total sulfur deposition in the case of long-term forecasts.

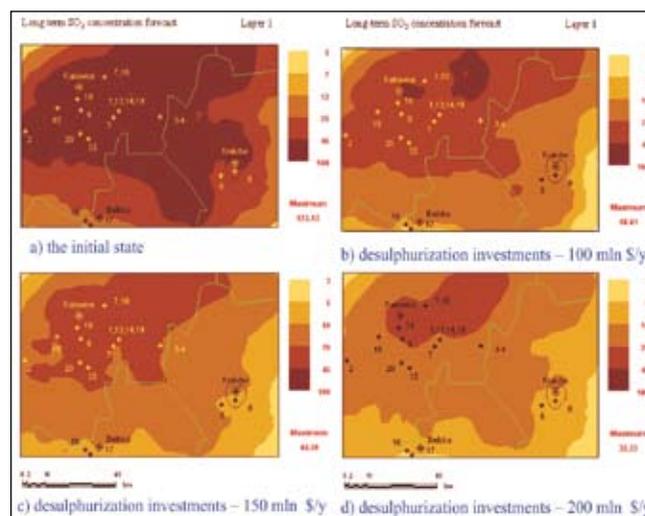
The mathematical description of air pollution transport is based on a set of advection-diffusion equations representing the transport, turbulent diffusion, and chemical transformations of the major pollutants. This description also includes a vertical wind profile, thermal effects, and dry and wet deposition processes. Numerical implementation utilizes the finite-dimensional approximation, based on effective and accurate computational algorithms.

Natural applications of the air quality model lie in forecasting the dispersion of pollutants, analyzing

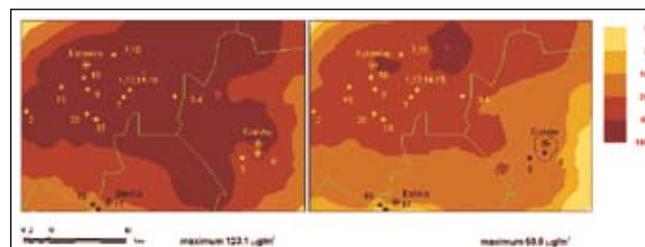
Short-term forecast of SO_2 [$\mu g/m^3$] concentration (three vertical layers) for the Warsaw Metropolitan Area



Optimal strategy of emission reduction (annual average SO_2 [$\mu g/m^3$] concentration) a) initial state; b) – d) optimal solution for assumed cost constraints



Optimal strategy of emission reduction (annual average SO_2 [$\mu g/m^3$] concentration): initial state (left); optimal solution for cost constraint 100 mln \$/y (right)



ecological results of some specific meteorological conditions, and evaluating the environmental impact of emission sources. More advanced applications integrate the pollution transport model with some economic, ecological, or technological standards and constraints. Such an integrated system makes it possible to formulate and solve more complex optimization problems related to air quality management or real-time emission control.

The system was applied to analyzing the optimum strategy of emission reduction in the case of the dominant power plants in the Upper Silesia Region.

This problem is formulated as an integer-type optimization problem, where the task is to assign a desulfurization technology to each plant so that the environmental objective function is minimized, subject to the constraint of the total cost of this operation. The dynamic properties of the air pollution model are used in the real-time emission control problem, where the task is to minimize the objective function in real time by respectively modifying the emission intensity of the controlled sources, according to the changing meteorological conditions.

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Decision Making System for management and operational control of municipal water and wastewater systems

OVERVIEW OF RESEARCH FINDINGS

This computer-aided system consists of several modules designed for the management and control of a communal water network and wastewater treatment plant, and comprises mathematical models of the operated facilities, optimization and control algorithms, monitoring systems, branch data bases and numerical map generators. The structure of the system is shown in Fig. 1.

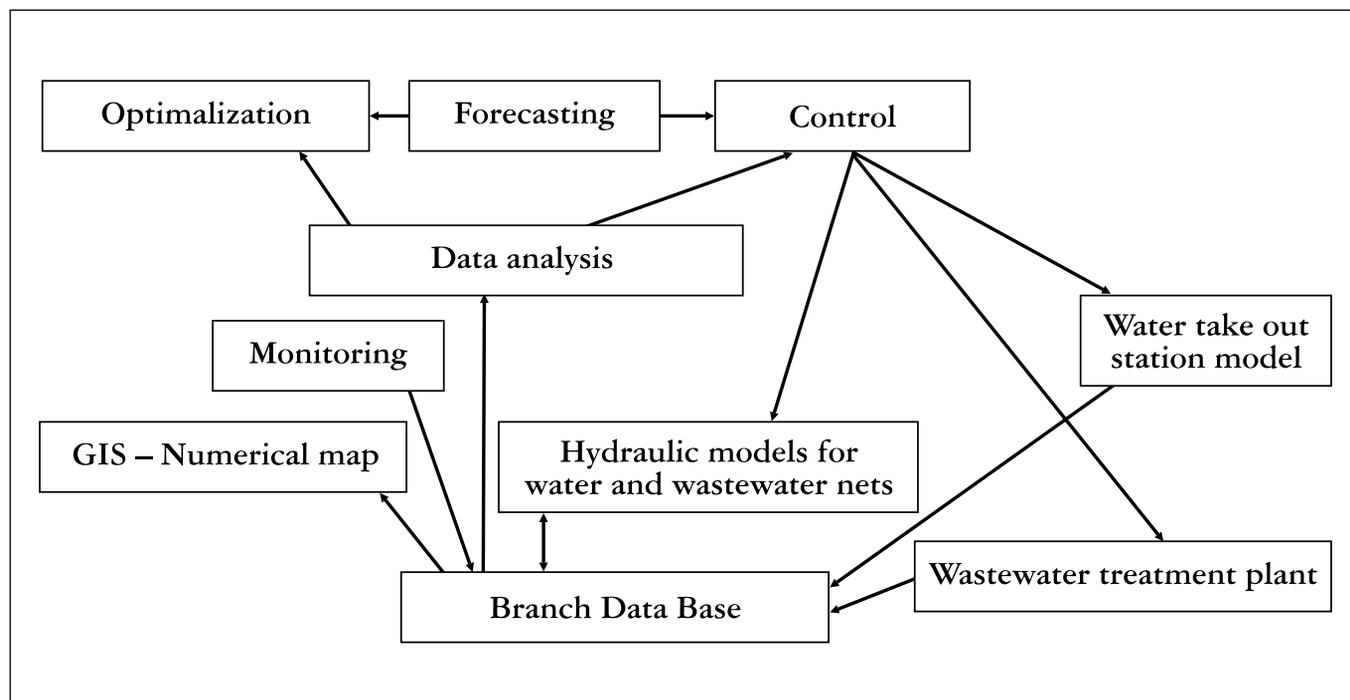
Hydraulic calculations and optimization of water networks are performed by the OHIO program (see Fig. 2), distributions of water flows and pressures in a water network can be visualized with the KRIPOW program using the kriging approximation for computing distributions (see Fig. 3), and wastewater treatment in the course of a sewage purification proc-

ess is simulated with the SOS program, as a physical model of the sewage treatment plant (see Fig. 4). The computer-aided DMSystem operates with the monitoring system PROCON developed and distributed by the firm Schulz-Infoprod, and with branch-oriented numerical maps based on GISystems GEO-MEDIA and G-Technology distributed by the firm Intergraph Polska.

The DMSystem has been implemented for the water network and sewage treatment plant of the the city of Rzeszów (see Fig. 5).

The estimated price of the system will depend on the size of the facilities and system, to be monitored, the number of applications to be introduced, and the scale of adaptation work to be done.

Fig. 1. Structure of the computer-aided decision making system for a communal water and wastewater system



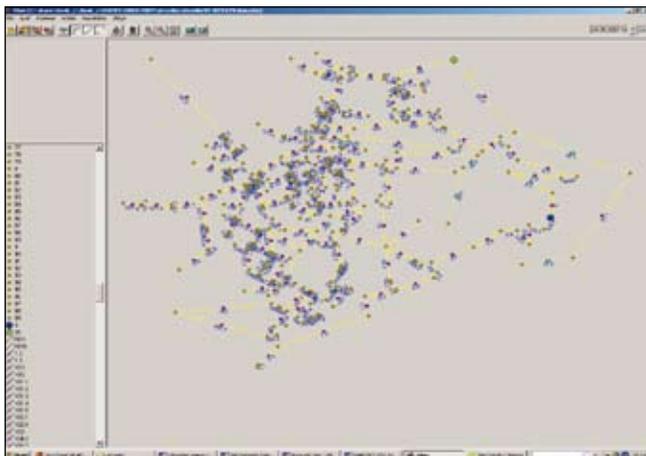


Fig. 2. Main screen of the OHIO software, modeling the communal water network

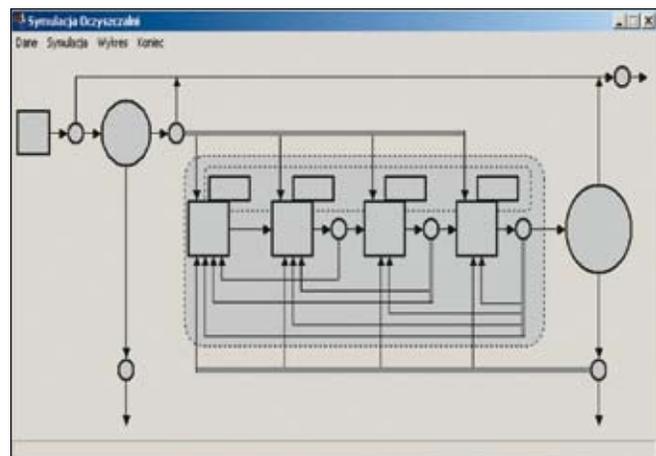


Fig. 4. Main screen of the SOS software for wastewater treatment plant simulation

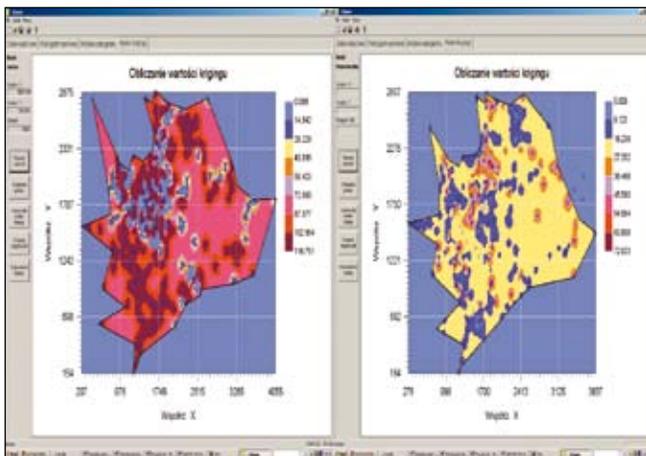


Fig. 3. Distributions of pressure (left) and flows (right) in a water network displayed by the KRIPOW software

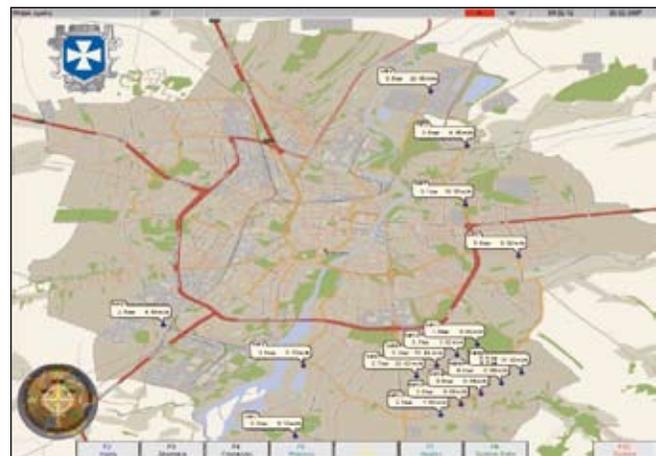


Fig. 5. Monitoring system operating in the water network in the city of Rzeszów

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Nanocrystalline multilayer coatings for biomedical applications produced using laser technology

■ OVERVIEW OF RESEARCH FINDINGS

Heart transplantations are carried out only in cases of irreversible damage to the heart muscle. When the heart is unable to cope with pumping blood, instead of replacing the organ, another alternative could involve adding an additional heart, such as the device presented here. The human organism cannot accept an intruder in the form of any other foreign body. One of the greatest challenges, from the point of view of materials engineering, is to identify a material causing the smallest possible interaction with the aggressive environment inside the body. Furthermore, such a material should be characterized by satisfactory mechanical behaviour. Consequently, titanium and its compounds such as TiN and Ti(C,N) have been selected for use in covering implants made of polyurethane, due to their good bio-parameters and mechanical properties. The method applied in such coating has involved pulsed laser deposition (PLD), which takes place at a relatively low temperature, in vacuum conditions or in a low-pressure gas environment with a precisely controlled chemical composition. The polyurethane element is placed in a special vacuum chamber, close to a rotating disc

made of pure titanium. When the coating process begins, four laser beams are fired at the disc. In reality, each beam is a series of extremely short light pulses lasting merely 10 nanoseconds, which hit the target 50 times per second. The energy density on the surface of the titanium disc becomes so great that each pulse causes a small amount of the material to evaporate rapidly in the form of plasma. This plasma is deposited on the nearby polyurethane element that will form part of an artificial heart. The process can be carried out at room temperature in order not to destroy the delicate and temperature sensitive polyurethane element of the artificial heart ventricle. As a result, an extraordinary thin film on the order of 50 or less nanometers is obtained and its thickness is precisely controlled. The deposited layers are uniform, have a nanocrystalline structure, adhere well to the substrate, and are characterized by flexibility and high chemical purity. Engineers from the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences in cooperation with the Foundation for Cardiac Surgery Development in Zabrze and Laser Center Joanneum

Element of the artificial ventricle POLVAD-IMPL with the coatings of titanium nitride (50 nm) obtained using laser technology



Research Ltd in Leoben in Austria are working to establish prototypes of an artificial heart ventricle.

The thickness of titanium nitride ranges up to 50 nm on a polymer base. The 3D coatings on elements of biomedical systems are of dimensions 300x300 mm and weigh up to 2000 g. The material is innovative in producing flexible coatings of increased biocompatibility (based on titanium nitride) on polymer elements.

The coatings will be applied on elements of an implanted heart-supporting ventricle developed within the framework of a long-standing project (the Polish Artificial Heart).

The scale of production will be a few dozen items per year (depending on demand). The cost of the ventricle is EUR 3000, that of the whole system approx. EUR 30 000. The device is protected by patent P-371147.

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Vacuum Hot Press for pressing at a pressure of 600 MPa and temperature of 650°C

■ OVERVIEW OF RESEARCH FINDINGS

The main portion of the instrument is a stainless steel cylinder with a number of slots designed for:

- controlling temperature (a digital pyrometer with a laser sensor),
- plugging in the vacuum system (a rotary pump, digital vacuum analyzer, air valve),
- plugging in the heating system (a coil connected with a high frequency generator),
- an eyehole for in situ observation of the inside of the cylinder during the pressing process, or for potentially installing a camera.

The cylinder is covered with the plate with the hole for the rod transferring force from the hydraulic press to the mould. All parts of the equipment are connected together by vacuum o-ring seals resistant to higher temperatures. The basic technical parameters of the device are as follows: maximum pressure – up to 700 MPa; maximum pressing temperature – 700°C at 200 MPa. The device can be installed on any press with variable pressure levels ensuring operation under a vacuum of 2×10^{-2} Torr and mould temperature control of $\pm 1^\circ\text{C}$. The device helps to compact powders and obtain porosity

of $<1\%$ with a mould heating rate of $50^\circ\text{C}/\text{min}$ and a mould cooling rate of $10^\circ\text{C}/\text{min}$, which enables fast repetition of the compaction process. Since a vacuum is applied, the press can be used to compact powders which oxidize easily – this makes it a unique device of this type in Poland. Additionally, it enables pressing to be carried out in special copper capsules, isolating the powder from e.g. lubricants or other agents (see photo). The capsule can be removed after the pressing process by simple machining.

Currently, the best results in the field of powder pressing are obtained via the process of Hot Isostatic Pressing (HIP). There are a number of companies producing devices of this type, but due to their very high cost and complex construction few research centers or factories apply such technology. The professional literature around the world shows a lot of interest in the development of new powder compaction technologies characterized by low cost and high efficiency. In this light, the presented equipment for vacuum hot pressing at a pressure of up to 600 MPa and temperature of 650°C seems to be innovative, to operate relatively simply, and to ensure good results.

Vacuum hot pressing device



Pressed copper capsule filled with reactive powder

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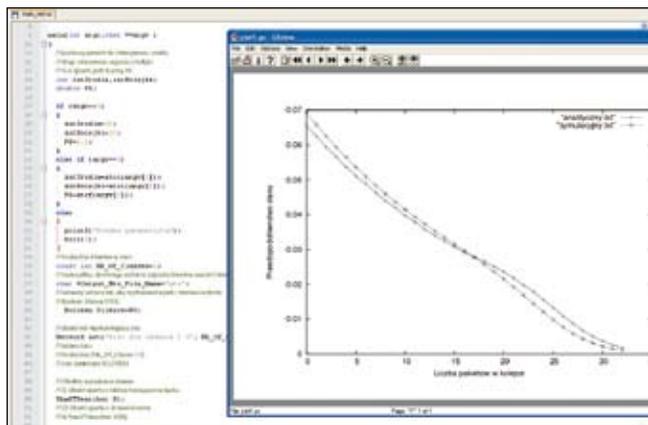
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Computer software for modeling and evaluating the operation of wide area computer networks and the Internet

OVERVIEW OF RESEARCH FINDINGS

This project deals with existing computer programs for modeling and evaluating the operation of wide area computer networks and the Internet. The computer software uses the following mathematical methods: Markov chains, diffusion approximation, and discrete event simulation. Moreover, it contains many realistic models of traffic intensity in transmission networks and constitutes a very useful tool for assessing the efficiency of proposed network con-



figurations, transmission control mechanisms, and network overload prevention.

The software is mainly in the C++ language, and can be run under both Windows and Unix systems. In terms of finite-state Markov chains, it is similar to other programs such as PEPS (France) and MARCA (USA). However, in terms of diffusion models and the transient state analysis, the software is innovative and original. What is new with regard to simulation modeling is that the software enables the dynamic balancing of processor load during diffused simulation processes. Its parameters depend essentially on the computers used. The Institute of Theoretical and Applied Informatics is working on a special computational cluster to carry out computations on an unprecedented scale.

The software has no commercial aspect; however, the Institute may use it to prepare an expert study on designed computer networks: their network topology, the selection of parameters, and traffic control mechanisms.

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Microwave device for high flow rate gas processing

■ OVERVIEW OF RESEARCH FINDINGS

This device is mainly for use in disposing of large amounts of harmful gases, e.g. freons, which are currently disposed of in an uneconomical and ineffective way via combustion. Furthermore, it can be used in the production of hydrogen via the process of methane reforming under atmospheric pressure, which has been tested in laboratory conditions.

The device ensures effective microwave power transfer (from 0.6 kW to 6 kW) to the discharge area under a wide scope of gas flow rates (from 30 l/ min to a few hundred l/min). Its dimensions are 3x2x1.5 m.

The anticipated scale of production should amount to six devices a year, at an estimated price of approx. EUR 25 000. The device is being promoted at inter-

national fairs (Hannover Messe) and via the Internet (www.plasmacenter.pl).



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Laser device for direct irradiation of electrical connection schemes on printed circuit boards (PCB)

■ OVERVIEW OF RESEARCH FINDINGS

The device is based on a semiconductor laser generating 375 nm wave radiation (a wavelength that is absorbed by generally available photopolymers applied in the electronics industry). Its use makes it possible to obtain patterns of electrical connections characterized by very high path packing density (50 μm /50 μm – path width/distance between paths) at a speed of up to 1 m/s. The device can irradiate patterns of up to 5 cm x 5 cm. Presently, printed circuit boards are produced by means of the photolithographic method, but the minimum path packing density for this method is 120 μm /120 μm . Consequently, this prototypical device could offer a very attractive solution for companies assembling SMD units (Surface Mounted Devices), some elements of which are very small.

The dimensions of the device are 0.8 m x 0.5 m x 0.3 m.

The anticipated scale of production should amount to 10 devices a year. The estimated price of the

product is EUR 25 000. The device is presently being promoted at international fairs (e.g. Hannover Messe) and via the Internet (www.lasercenter.pl).



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High-frequency coded ultrasound imaging system

■ OVERVIEW OF RESEARCH FINDINGS

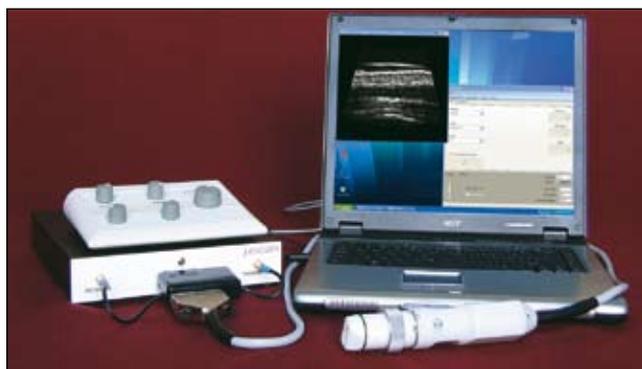
This system consists of an ultrasonograph module, a PC, and a scanning head. The unit enables an area of 7x7 mm to be imaged at a resolution of up to 50 μm , using 20-35 MHz transducers. The device uses coded transmission, which improves image quality and increases penetration depth for higher imaging frequencies.

The software/hardware enables switching between different excitation schemes, offering a unique possibility of optimizing the transmitted signal to a given application in real time. The small size, low power consumption, and low cost of the device result from the application of RF signal processing software.

The device can be used in dermatology, ophthalmology, and cosmetology.

The dimensions of the module are: 230 x 280 x 50 mm and it weighs 2 kg.

Production of the developed system can be launched after its certification. The approximate cost of the device (not including a notebook) will not exceed EUR 10 000. The versatility of the software and ultrasound transducers make the device useful for multiple purposes.



The μScan system

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Fluid models and the analysis of non-stationary signals applied for discharges in plasma thrusters

OVERVIEW OF RESEARCH FINDINGS

The usefulness of the proposed methods has been checked on the basis of experiments carried out in cooperation with the French Research Group “Plasma Propulsion for Space Systems” (GDR 2759 CNRS/CNES/SNECMA/Universités).

This method serves for analyzing discharge signals in plasma engines. Hall effect thrusters (HET) are widely used for the modification of satellite orbits. From the point of view of cosmic technologies, the most important feature of these thrusters is that owing to their efficiency they significantly reduce the weight of the equipment necessary during a given mission.

The proposed method and created numerical codes help to:

- reduce computation time in comparison to codes based on kinetic models and hybrid kinetic/fluid models,
- focus on physical processes responsible for maintaining plasma in the thruster and understand the problem of discharge stability under various working conditions.

For the purposes of experimental data analysis, the Institute is working on an EMD method enabling the information significant for the optimization of thruster work to be selected from non-stationary signal measurements (e.g. plasma pulsations). It is an EMD alternative for wavelet transforms. Since we have experience in applying this method to signal analysis using our own software, we propose this kind of experimental data processing.

The use of easier and less demanding numerical codes can give rise to considerable savings in terms of both money and time when fast answers as to physical process properties and construction guidelines are required. The estimated costs should be considerably lower than the expenses involved in the application of commercial tools. The inclusion of the new method into existing computer packages can considerably increase their value.

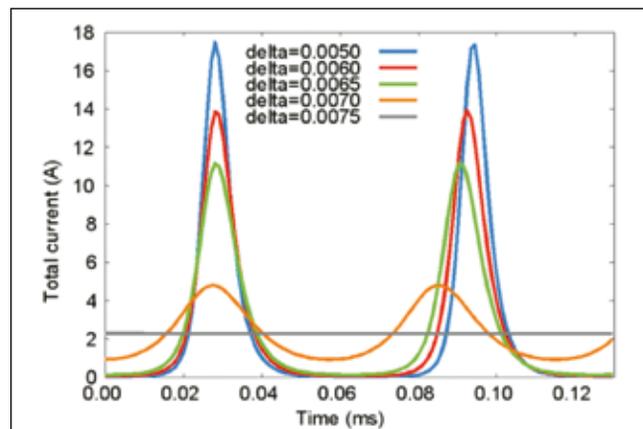


Fig. 1. Discharge current in the plasma thruster obtained in fluid models

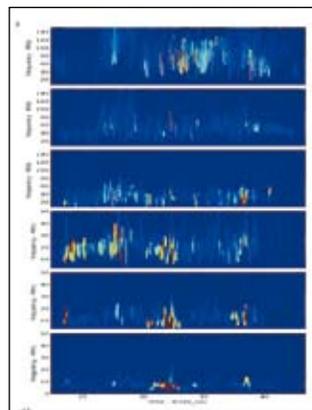


Fig. 2. Time-dependent signal power spectra (EMD)

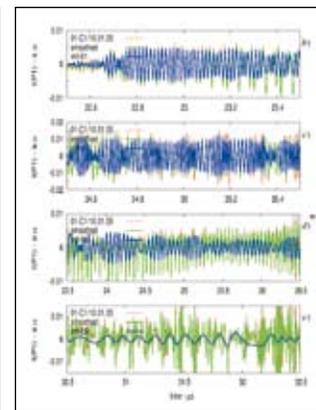


Fig. 3. Selected distribution modes (EMD)

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Hybrid laser-mechanical method of metal surface layer modification

OVERVIEW OF RESEARCH FINDINGS

This is a new hybrid method to modify a metal surface layer, combining laser processing (hardening or alloying) and material surface sliding burnishing. Characterized by all positive features of laser processing, the method helps to smooth out the surface without defects and introduce compressive stresses into the surface layers subject to laser processing. As a result, the method eliminates the process of polishing usually applied after laser processing with melting. Furthermore, the research shows an increase in the hardness of the surface layer and its resistance to friction wear.

The application of this hybrid laser-mechanical method for metal surface layer shaping in industry will help to eliminate the process of polishing and reduce time consumption and costs of upgrading elements by laser processing with melting. Simultaneously, the post hybrid processing surface layer displays better properties (hardness, resistance to friction wear, lack of tensile stresses) in comparison to the surface layer after laser processing.

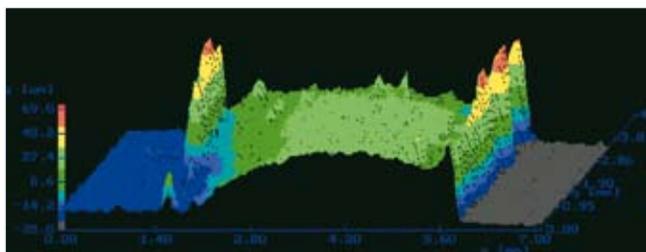


Fig. 1. Stereometric image of the surface after laser alloying

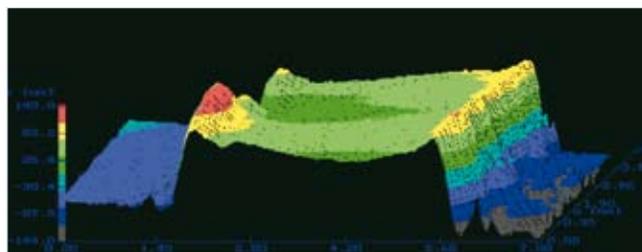


Fig. 2. Stereometric image of the surface after hybrid processing (laser alloying with simultaneous sliding burnishing)

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Laboratory benchmarks for validating numerical casting programs

OVERVIEW OF RESEARCH FINDINGS

This methodology for establishing experimental benchmarks helps to validate numerical programs used in the founding industry. The validation procedure consists in developing laboratory benchmarks for the solidification of a liquid with well-known thermophysical parameters, in a specific geometry, for fully controlled boundary and initial conditions. By using substitute liquids being the analogues of the founding materials analyzed, it is possible to measure velocity and temperature fields of the liquid inside the model geometry. Information is obtained using a computer analysis of shifts and color changes in the suspension of liquid-crystal indicators. The measurement of time-variable velocity and temperature fields, as well as the geometry and location of the phase-transition front provides the data necessary

for precise comparisons with numerical solutions. This enables the validation of the numerical model (the description of the physics of the process) and possible correction of model assumptions.

Experimental analysis of founding processes under industrial conditions is expensive and imprecise. The developed methodology, in turn, entails relatively low costs and high precision. It can be applied by R&D companies designing foundry industrial installations. Its use will considerably reduce trial costs associated with the implementation of new mould filling technologies or existing configuration changes (with regard to location, filler geometry, thermal conditions, mould-filling velocity, etc.).

Website: <http://fluid.ippt.gov.pl/pivtmovie.html>

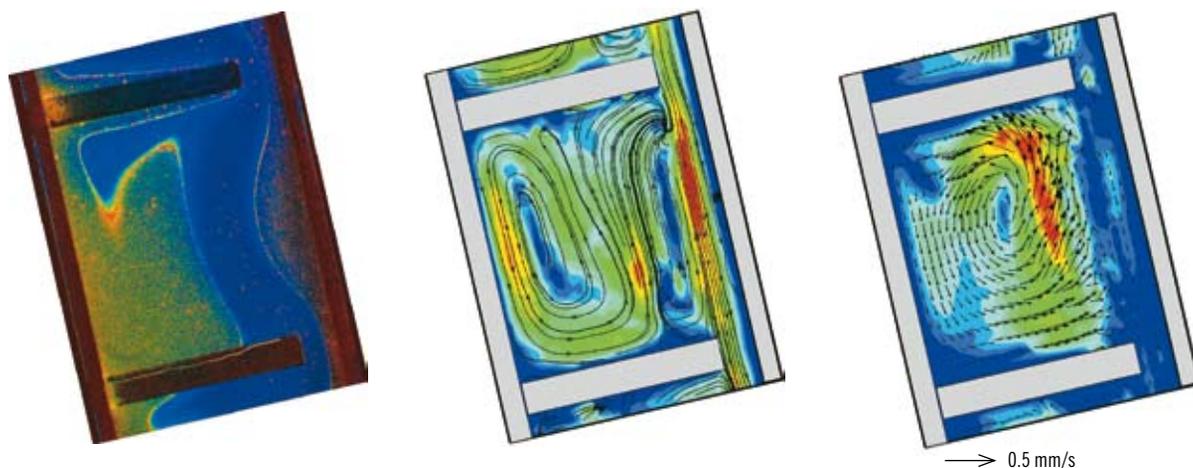


Fig. 1. Validation experiment shows temperature and velocity fields in the process of mould filling

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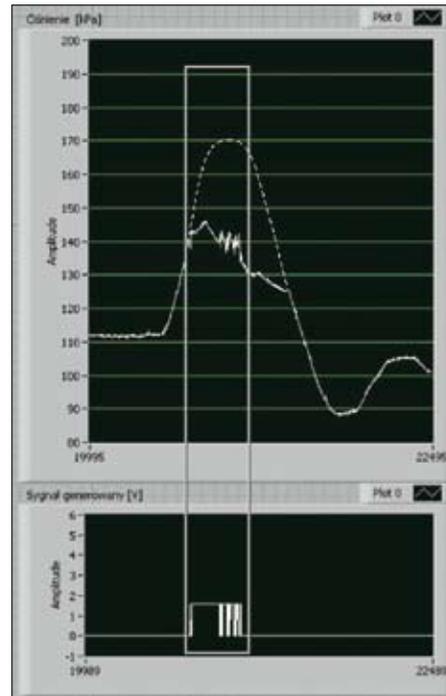
A semi-actively controlled magnetorheological clutch as a damping element of driving systems in power-generating units

■ OVERVIEW OF RESEARCH FINDINGS

This system adapts the stiffness of a magnetorheological clutch in order to eliminate or minimize torsional vibrations causing temporary dynamic overloads in the electromechanical system – it represents a qualitative change in comparison to currently used stiff clutches.

The diameter of the designed clutch is consistent with the diameter of the shaft on which it is installed, while its weight depends on the mechanical system (~10kg).

The clutch can be applied in compressors, turbo-generators, ventilators, crushing machines, drilling machines, etc. The potential addressees of the product are clutch or gear manufacturers. The authors of the invention have experience in dynamic system control using magnetorheological fluids for application in undercarriages. The product may be promoted by the Foundation Supporting the Transfer of Smart Technologies – INTECH.



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Nanofibre electrospinning for biomedical uses

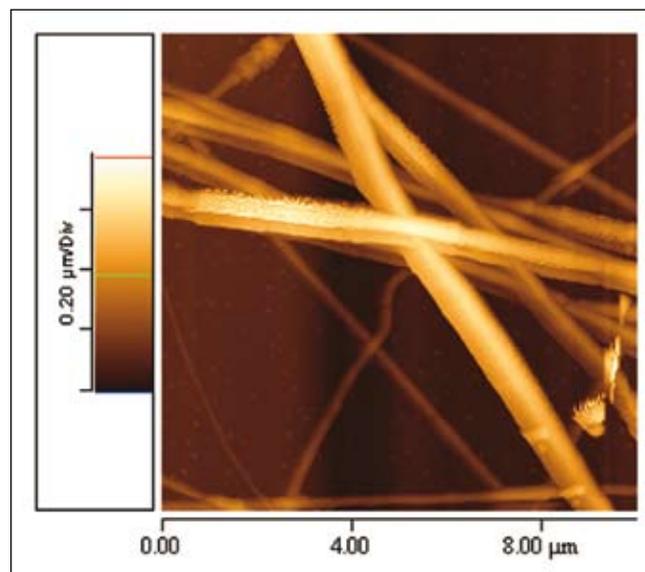
OVERVIEW OF RESEARCH FINDINGS

Nanofibre electrospinning is one of the cheapest and most effective methods of producing nanomaterials. Nanofibres are already used for filtration, and are presently being put to intensive tests with regard to their applications in tissue engineering. Fabrics obtained by electrospinning are recognized by cells as native extracellular matrix (ECM), and after they are colonized by the cells, the system creates artificial tissue or an organ from the donor's cells. Nanofibre materials can help in the integration of ceramic osseous bioimplants and skin reconstruction; they can also be used for the production of biodegradable internal or external dressings. The materials can have multiple applications in drug delivery systems (DDS), while recent discoveries show that it is possible to use them in protein drugs.

The product is very light. The scale of its production and investment costs will be low. However, the price of the final product (i.e. the relation between the product price and its weight) will be very high, as well be the intellectual/scientific added value. The nanofibres will be produced by spin-off companies. The product may be promoted among specific groups of professional doctors at conferences and in bulle-

tins. It may possibly be sold via the Internet. Nanomaterials based on proteins or protein mixtures are recent discoveries and can be patented for the production of various therapeutic biomedical systems.

Website: <http://fluid.ippt.gov.pl/nanofibres/>



AFM image of electrospun nanofibres

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