SUMMARY

of the main results and scientific contributions of
Assoc. Prof. Dr. Eng. Elena Georgieva Koleva

The scientific works are mainly in the fields of mathematical modeling, statistical methods, optimization and control of technological processes, the study of physical processes, and applications of the generation of intense beams of accelerated electrons and their interaction with materials. New data have been obtained, regularities have been studied and new research methods have been proposed, models, algorithms, and computer programs have been developed for numerical and empirical modeling of processes at the generation of intense electron beams, as well as for simulation of the processes of electron beam processing of materials. Approaches and new methods for control and optimization of the operation of electron beam installations and technological processes are proposed and experimentally verified. Optimization approaches have been developed for of electron beam welding, refining using electron beam melting, as well as for the process of synthesis of biomaterials by irradiation in linear electron accelerators, computer programs for simulating the processes of exposure and development during the obtaining of submicron and nano-dimensional electron-lithographic images are developed, the properties of the obtained materials have been studied and the technological working conditions have been optimized under different requirements for the final characteristics of the materials.

Penetration of accelerated electrons into polymer layers
(exposure and development at submicron electron lithography)
(B1, B2, B3, B6, B8, B9, Г18, Г19, Г20, Г30, Г33, Г38, Г43).

Electron beam lithography installations are the most expensive technological equipment in the microelectronics industry. Electron beam lithography allows direct printing of nanostructures with sizes typically below 100 nanometers and even smaller sizes up to below -10 nanometers. Achieving structures below 100 nanometers by electron beam lithography is a very sensitive process, which is determined by various factors, starting with the choice of the polymer material of the resist (changing its properties when irradiated with an electron beam) and ending with the development process. Resist materials are key elements in electron beam lithography and their characteristics determine the final results of patterning structures.

Nowadays the research activities for the development of nanodevices require patterning in different combinations of thin films and substrates, e.g. III-V semiconductors (GaN, GaInN, AlGaN, AlGaInN, GaInN), photonic crystals, etc. A methodology for simulation of the characteristics of electron beam resists has been developed, which is suitable for the effective and precise control of the structural dimensions in the electron beam resist, which is used as a mask for fabricating structures on different thin layers.

The processes of exposure and development of polymer resists are simulated and the characteristics of the spatial distributions of the transmitted energy and the energy distribution of
the penetrated electrons are calculated for a number of practically important cases. The influence of the development conditions – i.e. the radiation dose, the type of developer, the thickness of the resist, the dimensions of the developed structure, the parameters of the beam, and the substrate on the results of the process was studied. It is shown that the sensitivity and the contrast parameter are related values. Therefore, the resist/developer pairs have high sensitivity at low contrast or allow the development of high-contrast structures when exposed to high doses.

Data on the behavior of the resists used in nanolithography were obtained. Numerical calculations are made for the proximity function when exposing structures or thin layers of different resists or high-temperature superconductors. The results of the computer simulation are necessary for the introduction of corrections in real electron-lithographic processes related to the proximity function. Models have been developed to estimate the parameters of the proximity function for different thicknesses of positive polymethyl methacrylate resists. The general problems and limitations of the submicron lithographic methods are discussed, the tendencies of development of these technologies are shown.

A study of the sensitivity was performed to characterize three electron polymer resists: two positive resists polymethylmethacrylate methacrylate (PMMA) (Microchem) and AR-P 6200 (CSAR 62) (Allresist), and an epoxy-based negative resistor SU-8 (Microchem). Experiments have shown that the characteristics of resists, including their sensitivity and contrast, are influenced by the energy of the electrons, the nature of the resists and the substrate, the type and composition of the developer, and the general conditions of the development process. Data on the spatial distribution of the energy deposition function in the studied resists were obtained by Monte Carlo simulations. Simulation of the characteristics of the resists was performed and neural models for prediction of the profiles of the developed resists for parameter optimization and control of the obtained geometry of the developed structures in the resist were evaluated.

The characteristics of the development process of the new positive chemically enhanced resist CSAR 62, which is a cheaper alternative to ZEP nano-resists and has great possibilities for applications in nano-lithography, has been studied. The contrast curves of the studied resist were constructed experimentally and a model for the nonlinear characteristic of the rate of manifestation of this resist depending on the change of the exposure dose and different time of development with developer AR600 was evaluated. Photonic crystal structures were obtained – a hexagonal lattice with different diameters and periods of the openings, and the exposure was performed with a Gaussian beam to obtain an optimally round shape of the openings.

The HSQ (Hydrogen Silsesquioxane) negative resist is used as a high resolution resist below 10 nanometers. Structure in HSQ with high contrast and high resolution has many potential applications. Lithographic parameters in thicker resist films have been studied because a resist thickness of 150 nanometers is not sufficient for repeatable reactive ion etching of various thin films for many applications. The main emphasis is on the study of the dependence of the line width on the dose of exposure in thick HSQ resists and simulation of the resist profiles.

The influence of the dose of electron beam exposure, the thickness of the PMMA resist layer on the silicon substrate and the accelerating voltage on the geometrical characteristics of the profile of the resists developed after exposure were studied. A series of numerical experiments were performed, which represented exposure with an electron beam in vacuum and development
of a structure of 5 parallel lines with a width of 0.3 µm, located at a distance of 0.4 µm from each other and the profile dimensions obtained in the middle of the centerline of the positive resist PMMA. Methyl isobutyl ketone (MIBK), isopropyl alcohol (IPA), MIBK / IPA 1: 3 solution are used as developers. Regression models were estimated, and by applying a robust engineering approach, models for the mean values and the variances of the geometric characteristics of the resist profile were estimated. The obtained models allow parameter optimization under production conditions and the presence of errors in the factor levels to obtain resists with high quality and reproducibility. The solutions obtained by multicriteria optimization are robust (insensitive) to errors in the factor levels. Appropriate regime parameters are selected depending on the specific requirements for the size and shape of the exposed and developed profiles of the resist by applying a multicriteria method for process optimization.

A study was performed for exposure and development of a positive resist polymethyl methacrylate with a thickness of 100 nm on a Si substrate at an electron energy of 20 keV. The distribution of absorbed energy was simulated using the CASINO software product and the TREM simulation software developed in IE-BAS. The resist development process is carried out through the SELID program. Results related to the estimated dissolution rate based on the obtained experimental data are also presented.

A software application program for electron beam lithography based on estimated neural and regression models describing the dependencies of the geometrical characteristics of the cross-sections of positive resist polymethyl methacrylate (PMMA) after electron beam exposure and development with methyl-isobutyl ketone (MIB) parameters has been developed. Electron beam lithography depending on the process parameters electron beam lithography: accelerating voltage, resist thickness, exposure time, and exposure dose. The program allows determining the dose to clear of exposure, comparison of the two modeling approaches, as well as subsequent optimization based on the obtained models.

A study of the developed profiles and parameters of the electron beam lithography process in a positive PMMA resist was performed. The experiments were performed using a process control system electron beam lithography Elphy Quantum (Raith) mounted on a scanning electron microscope (SEM) Quanta FEG (FEI) with field emission cathode and Gaussian intensity distribution. The study was performed for 1300 nm thick PMMA resistors on a Si substrate at 30 keV electron energy. The development is performed using a developer MIBK: IPA 1: 3 and development time of 60 seconds. Models of the dependences of the developed widths of the profiles on the exposure doses at different depths in the developed PMMA resists were evaluated. Simulation results were obtained for the developed resist profile geometry at different exposure doses. Comparisons were made between the experimentally measured data and the calculated data on the geometry and dimensions of the obtained profiles in PMMA resists to verify the evaluated models and good compliance was observed. The models can be used to predict and optimize resist profiles and to select appropriate process conditions.

Electron beam welding (EBW)

B7, B10, Г12 - Monograph, Г17, Г26, Г27, Г32, Г35, Г41, Г48, Г.49.
The physical and thermal models of electron beam welding are specified. The ion self-focusing (presence of plasma) and the scattering of the beam in the vapor of the material, as well as the hydrodynamic processes in the liquid bath, are taken into account. The need to use a non-stationary thermal model of the process is shown. Methods for calculating the regimes of electron beam welding are proposed. In the case of thin-wall details, the methodology is based on the concept of heating the sample with a linear moving heat source. In the case of thick-wall details, due to the complexity of the processes (formation of a crater in the liquid pool full of metal vapor and plasma and their interaction with the beam), thermal models allow predicting only in order the dimensions of the weld cross-section parameters (depth and width). Applying experimental design methodology and statistical analysis of the experimental data, models that accurately predict the geometry of the cross-section of the weld for the studied material and machine are obtained. Regression models, as well as models obtained by applying trained artificial neural networks, can be used in process automation and in computer methods for optimization of the technological results, as well as in computer expert systems to support operator decisions.

New data have been obtained by studying the collected secondary particles from the plasma generated in the process of electron beam welding. The parameters of the plasma in the crater in the welding pool and in the space above the interaction zone have been studied theoretically and experimentally. With a positive collector potential exceeding the plasma potential, the collected electron current is a non-independent arc discharge current burning from the overheated sections of the crater walls, where the electrons that have managed to penetrate fall. In this way, the plasma signal carries information about the instabilities in the beam/crater system. Excitation of ion-sound acoustic oscillations has also been observed if the collector/interaction zone distance is large. At low positive potentials of the collector and at collection of plasma ions nonstationaries of the registered signal are also observed. In all the cases described, the proposed summing of the randomly registered signals (called the coherent accumulation method) proves useful for the control of the technological process and for the analysis of the ongoing phenomena, since according to the law of large numbers and the central limit theorem of probability theory the result of this summing random signals is not a random variable.

Aspects of the use of welding powerful concentrated electron beams are considered. Electron beam welding is a highly efficient, energy-saving process for joining large thick-walled metal parts. A comparison of electron beam welding with electric arc welding is made. The efficiency of heating the metal from the arc depends on the welding process and does not exceed 50 - 65%. Multi-pass welding is used for arc welding of thick-walled parts. With this technology, the value of the electricity used to form the weld increases significantly. In electron beam welding, a deep and narrow seam is formed. This allows welding of thick metals with a minimum of energy invested in the welding joint. The heating efficiency of the metal reaches 95-98%.

A method of controlling the focusing regime of the electron beam has also been developed. This method is based on the parameters of the secondary emission current in the plasma generated above the welding zone. For this purpose, a collector with a positive potential is located above the welding zone. The plasma formed by the ionization of metal vapors by the electron beam serves as a conductive medium. The current from thermoelectron emission from the zone of interaction of the beam with the crater walls in the liquid metal has significant values. The high frequency component (10-30 kHz) is selected from the spectrum of the plasma collected by the
plasma and is used to control the focus position. The empirical distribution of the current density of the extracted signal in the range of amplitudes well reflects the shape of the channel in the molten metal. This allows control of the beam focus during electron beam welding and achieving a maximum concentration of heating power in the welding zone. The method allows to obtain the maximum ratio between the depth and width of the seam and ensure high energy efficiency of the process.

The optimization of the process of electron beam welding in vacuum of 1H18NT stainless steel on the basis of experimental data is considered. The influence of the change of the process parameters on the electron beam power, welding speed and the distances from the magnetic lenses of the electron gun to the focus of the electron beam and to the surface of the sample is taken into account. Neural and regression models for the cross-sectional area, depth and average width of the welds were evaluated, on the basis of which a multi-criteria parametric optimization of the electron-beam welding process was made. The obtained results show a good correspondence between the experimental and the predicted values of the studied geometrical characteristics of the welds. The relatively small number of experimental data gives an advantage to regression analysis as a modeling approach, and the results would be better if standard experimental plans were used to evaluate the models themselves. Increasing the number of experimental data will also improve prediction through neural networks. An applied interface for multicriteria graphical optimization of the parameters of the process of electron beam welding of stainless steel based on the evaluated neural and regression models has been developed. Operators have the ability to select a range of desired geometric characteristics, and determine the models to be used in the optimization. The application of the proposed methodology will help to increase the quality of the welded joints obtained by electron beam welding.

For electron beam welding of stainless steel type 1H18NT models are evaluated for the dependences of the geometric characteristics of the obtained welds when varying the process parameters - electron beam power, welding speed (electron beam motion), distance from the magnetic lens to the focus of beam and to the surface of the samples. Under production conditions there are variations in the process parameters, which affect the variations of the geometric characteristics - depth, width and cross-sectional area - of the welds. To improve the quality of the produced welding joints from the point of view of reducing the scattering of their geometrical characteristics and increasing their reproducibility, a methodology for robust engineering design was applied, and for each characteristic two models were evaluated, describing the mean value and variance of the initial characteristics. under production conditions. Optimal areas and modes for the process parameters are obtained by setting different requirements for the studied geometrical characteristics of the welded joints by appropriate methods for multicriteria optimization - graphical optimization and Pareto optimization.

The automation of the available equipment, which aims to increase its efficiency and repeatability of the obtained results, as well as the stabilization of the process parameters, must be integrated into an engineering support system consisting not only of operator monitoring but also of several subsystems for control of equipment, data collection and processing, information analysis, system management and decision making. The available and additional technical means for automation are analyzed. For the automation of the electron beam welding process, algorithms have been developed for the automated control of the vacuum and cooling systems of an electron beam.
beam welding installation in IE-BAS. The temperature of the diffusion pump and the pressure in the zone of low and high vacuum were identified by conducting a series of experiments and evaluating models for the transient characteristics of these parameters. The obtained experimentally transient characteristics can be used to optimize parameters that are critical for the duration of the time to reach operating mode and the time to stop the installation. The estimated parameters of the transient characteristics are specified by minimizing the root mean square error with respect to the time delay values. A significant reduction in the shutdown time of the entire installation has been found when using a fan to cool the diffusion pump. The need for replacement or introduction of additional and auxiliary technical means for subsequent optimization of the time required to reach the operating mode and to stop the installation for EBW was discussed. A ladder diagram and functional scheme for automatic control based on a programmable logic controller of Siemens Simatic 300 for the stages of commissioning and shutdown of the installation have been developed.

For the application of the new technologies for electron beam welding, the equipment for EBW is formed as a complex object, containing highly stabilized electrical sources and electronic units, reliable and efficient vacuum system, technological camera with a precise 3D manipulator. They become truly software-controlled programmable systems with high efficiency and excellent reproducibility. Highly advanced automated processes, including vacuum system with pump and pressure control, cooling system control, manipulator control, high voltage and emission current control, electron beam motion control and characteristics, and computer-based automatic distribution control of the beam power must be integrated based on the use of Manufacturing Operations Management (MOM) systems. A model of such an integrated system for control of the electron beam welding process has been developed based on the development of a MOM system and ISO / IEC 62264 standard, providing for the inclusion of additional processes: surface modification, electron beam evaporation, selective melting and diagnostics of an electron beam. The main goal of the MOM system for electron beam welding is to integrate and organize the knowledge about the process and to use this knowledge to improve the possibilities for modeling and control, their efficiency, adaptability, flexibility and reconfiguration, as well as integration of other technological processes.

**Electron beam melting and refining**

(В4, Г14, Г16, Г22).

The features of the melting and refining processes in the different zones of the process have been studied theoretically and experimentally: on the forehead of the molten sample, in the drops of liquid metal and in the liquid bath in the copper water-cooled crystallizer in which the finished casting is formed. Computer programs have been developed to simulate the processes of heat distribution and mass transfer in the liquid layer of the front of the molten sample and in the bath in the resulting casting. It is shown that the dissolved gases are released at the beginning of the melting process, and the optimization of the process requires a properly selected distribution of energy input. Data on the limiting process for reducing impurities under different thermodynamic conditions in the liquid metal and depending on the other controlling factors of the process were obtained. For example, the optimization of oxygen uptake from the liquid bath, in the form of non-metallic inclusions in the starting metal, depends on the concentration of impurities and ongoing
thermo-chemical processes. On this basis, the advantage of using unrefined copper as a raw material for the production of pure oxygen-free copper, as well as the addition of carbon powder and contact with a carbon crucible in the refining process, has been shown. Similarly, by properly selecting the temperature of the liquid titanium and its melting rate, the oxygen content of the resulting casting is optimized by electron beam melting and refining.

The use of vacuum condensate to obtain separate components in copper refining is justified. A new explanation of the roughness of the cast blocks is proposed, related to the non-stationary thermal processes in the zone of contact of the liquid metal with the water-cooled copper crystallizer. It is a basis for increasing the yield of the technological process. The obtained pure metals and alloys are used for the production of laser mirrors for high-power lasers, crucibles for crystal growth, targets for ion sputtering and deposition of thin layers in microelectronics and instrumentation, etc.

A quasi-stationary two-dimensional thermal model for electron beam melting in a crucible was used to simulate the temperature distribution in the cast copper ingots by drip electron beam melting. Regression models for the dependence of the shape of the crystallization front (melting depth, width, volume of molten metal) on the change of the process parameters - electron beam power, beam radius and casting speed are evaluated. The surface of crystallization of the melt and its reaching the outer wall of the ingot are discussed. The shape of the crystallization front controls: the formation of the dendritic structure, the uniform removal of impurities, the process of metal refining, the ratio of surface to volume of molten metal, the roughness of the side walls of the resulting ingots and thus the quality of the ingots. It is used to calculate the shape and heat fluxes through different surfaces, as well as the shape and volume of the liquid bath. Simulations were made for different materials (Al, Cu, Ti). It has been shown that much of the heat is lost through the contact zone of the ingot / cooling crucible. It has been demonstrated that the rupture in the crystallized hardened crust around the liquid pool at the top of the ingot is due to the intense heat exchange in the area of the cooling crucible. By simulating the thermal processes in the ingot, a study of the influence of the thermal conductivity coefficients under different boundary conditions on the energy flows through the boundary surfaces and on the volume of the liquid pool is performed. Regression models were evaluated for the relationships between energy losses from different parts of the ingot surface and for the volume of the liquid pool, depending on the input power of the electron beam, the thermal conductivity coefficients and the width of the ingot / crucible contact zone. The results allow the choice of combinations of factors whose role is not fully understood and is difficult to measure directly. As a result, process optimization and equipment design can be realized.

The effects of the parameters of the electron beam melting (EBM) process on the removal of impurities during the processing of technogenic materials from molybdenum and tungsten for obtaining pure metals have been studied. The obtained results show that repeated electron beam melting is most suitable for refining man-made materials with high concentration of Mo and W. In double electron beam refining of technogenic molybdenum material, the total removal efficiency and removal efficiency of each of the controlled impurities increases 1.5 to 2 times after the second melting process and the molybdenum concentration increases by more than one order of magnitude compared to the concentration in the starting material. At EBM of spent tungsten electrodes, the results obtained are: higher refining efficiency is obtained by increasing the number
of melting cycles, and not by increasing the power of the electron beam. The highest achieved purity of tungsten (99.9%) is obtained after double treatment by electron beam melting and the refining efficiency is 95.67%, which is higher than the removal efficiency obtained in a single melting cycle (88, 31%). Efficient technological regimes (technological parameters) for production of metals are offered, which meet specific requirements for high purity and quality structure after treatment by EBM of molybdenum and tungsten technogenic materials.

Models for the mean values and variances in the typical for production conditions case of multiple correlated initial values (correlated final impurity concentrations in EBMR of Ti) when heteroskedasticity of observations and errors in factor levels are present are evaluated. For evaluation of the parameters and models in this case a new combined method is applied [PhD abstract of eng. Elena Koleva]. Both correlation and heteroskedasticity must be taken into account to improve the accuracy of prediction through the estimated models. A great advantage of the proposed method is the ability to use raw industrial experimental data, instead of the necessary very accurate estimation of the parameters of the regression models without errors in the factor levels, made, for example, in the laboratory. The proposed approach is applied to study the kinetic dependences of impurity concentrations and material losses on the technological parameters during refining by Ti CRT. An easy-to-use graphical user interface has been developed to help improve the quality of the resulting Ti units for laboratory and industrial applications without making expensive investments in raw materials and automation. The available database can be updated with new experimental data and thus the range and predictive models will also be updated. The resulting ingots or refined metals or alloys will have low concentrations of impurities and variations in quality characteristics in industrial production conditions will be minimized. In this way, the overall quality of the Ti units produced will be improved overall.

**Synthesis and optimization of electron beam treatment of materials based on biopolymers**

(Г13., Г31, Г34, Г36, Г40, Г44, Г47).

Applications of electron beam technologies for wastewater treatment, food processing, etc. have been developed and proposed, as well as an approach for optimization of electron beam induced copolymer grafting has been developed. Accelerated electrons have enough energy to break chemical bonds in organic materials, including polymers. In general, the formation of free radicals is the result of breaking chemical bonds. Electron beam (EB) applications are realized on the basis of the formation of these radicals. These processes can be classified according to the consequences arising from the formation of free radicals: EB polymerization, EB crosslinking, EB separation and EB induced grafting of copolymers.

A method for modification of different types of starch by addition of acrylamide and electron beam irradiation, for synthesis of water-soluble copolymers with flocculant properties has been developed. The electron beam induced grafting of acrylamide and corn / potato starch in linear electron accelerators with different average energy, with different radiation doses, dose rates and different proportions of the acrylamide and starch content was studied. The characterization of the synthesized copolymers was performed by the following performance quality parameters: monomer conversion coefficient; the residual concentration of monomer; apparent viscosity;
internal viscosity and Huggings constant. Criteria for multicriteria optimization are formulated, which are related to the economic efficiency of the process, the low toxicity, the efficiency of the copolymer in flocculant processes and the good water solubility of the synthesized copolymers.

An approach based on robust engineering design is proposed, evaluating models for the mean values and variances of the studied quality indicators (regression, neural networks) depending on the variations of the parameters of the process of synthesis of water-soluble copolymers with flocculant properties. The influence of the addition of silver on the process is also analyzed by applying an approach for combined modeling of quantitative and qualitative factors.

An approach for generalized robust optimization of the connection process due to electron beam irradiation is proposed. The approach is based on the application of the generalized desirability function - generalized robust optimization - for multicriteria parameter optimization in case of robust engineering design, based on estimated models for the mean values and variances of the quality characteristics. Multicriteria optimization has been made with the defined requirements for the mean values and variances of the quality characteristics with different modifications of the approach for generalized robust optimization. The modifications are related to the determination of different weights for the individual desirability functions and the general desirability functions for the mean values and variances. The proposed approach involves taking into account the accuracy of the estimated models, expressed by their coefficients of determination. Applied software based on the proposed methodologies and evaluated models has been developed.

New experimental data related to the synthesis of combined biopolymers - based on hydrogel, obtained by electron-induced crosslinking. Two different biopolymers, xanthan gum and carboxymethylcellulose, were used to prepare the hydrogel in the presence of sodium salts of acrylic acid and a water-soluble binder. The influence of the different concentration of xanthan gum, carboxymethylcellulose and binder, the influence of the radiation dose on the parameters of the synthesized hydrogel, which are: gel fraction, degree of swelling, modulus of elasticity and viscous modulus is studied by estimation of regression models.

Electron beam irradiation in both groups of experimental studies is performed on linear electron accelerators at the National Institute of Laser, Plasma and Radiation Physics (Magurele, Romania) under two bilateral international projects of the Institute of Electronics - BAS and NILPRF - Romania.

**Nanotechnology**

Г11 – Monograph, Г24, Г25, Г21, Г23.

The monograph discusses the results of the study of carbon nanomaterials, nanostructured silicon, and silicon composites, the self-organization of nanosized materials, their properties and applications. The technologies of their production, their properties, and their areas of application are described. A summary of studies of self-organizing nanoscale structures, such as fullerenes, carbon nanotubes, and graphene, has been made. Functional devices of photonics, bio-, cryo-, molecular electronics, magnetoelectronics, and spintronics, sensors and mechanical electro-nano-components, etc. are considered.
The authors from the Bulgarian-Ukrainian team - G. Mladenov and E. Koleva from IE-BAS, were awarded Diplomas from the Ministry of Science and Education of Ukraine, the Academy of Pedagogical Sciences of Ukraine and the Kiev Chamber of Commerce and Industry for special creative contribution to the educational process. The Diploma was also awarded to the team for writing the monographs, signed by the Minister of Education, Science, Youth and Sports of Ukraine, as well as by representatives of the National Academy of Pedagogical Sciences (Curriculum Vitae Appendix 1).

Possible applications of nanotechnologies and nanostructures in various fields such as electronics - in external storage devices, as well as for biosensor systems and their characteristics based on nanostructured silicon are considered.

Thin films of TiO$_2$ were obtained on silicon support by electron beam evaporation and the use of an electron gun with a plasma cathode. The thin layers were obtained after titanium deposition and subsequent thermal annealing in an oxygen medium. At different oxygen pressures and distances between the titanium target and the substrate. These results demonstrate the better results of plasma cathode electronic rifles compared to conventional thermocathode electronic rifles, especially when operating at low vacuum and high reactive gas pressure. The dependencies of the thickness of the thin layer on the electron beam power density and the deposition time are also presented.

**Modeling and optimization of pharmaceutical processes**

The study presented a Quality by Design QbD approach for quality improvement of products in pharmaceutical manufacturing via appropriate designed cleaning processes.

Given the specificity of the cleaning processes, the use of classical linear regression analysis is not always the best choice, since some of its assumptions can be violated. The experiments are often carried out in presence of noise, which results in unequal initial levels of equipment surface contamination and it, in turn, affects the final results and models. For the considered cleaning process, kriging is the more reliable method for modeling and robust optimization, as its prediction appears to be more accurate than the standard regression model.

The dependence of the product residues, which remain on the equipment surfaces after cleaning, on the input process parameters is not a purely linear function, but it has an optimum, where any further increase in parameters will not result in a significant change in the output product residues on the equipment surfaces. Using the robust parametric design, the chosen optimal conditions will also assure the minimal variance in their values. Therefore it is possible to design a reliable, robust, and cost-effective cleaning method simultaneously. For this particular cleaning validation study, based on the validation data at kriging optimal operating conditions, we achieved a 74.4% reduction of the average value of the active substance residues; a 99.4% reduction of the variance, and a 28.9% cost reduction. In addition, the development time was reduced from more than 3 months to less than 2 weeks and the reduction in validation time was 90%.

An analysis of the stability (durability) of a medicinal product was made by evaluating linear regression models. The aim is to monitor the qualitative characteristics of medicinal products over
time under the influence of various conditions such as temperature, humidity, light, etc., to
determine the shelf life, and retesting and to determine appropriate storage conditions of the drug.
Three batches were considered during their storage for one year. The displacement of the
estimated models in each batch is analyzed, and the application of a generalized model for this
specific case is discussed.

Experimental data from 135 batches of medicinal product were obtained and analyzed.
The studied quality parameters are tablet strength, analysis of the active substance, acid
resistance, decomposition, water content and dissolution after 150 minutes and 165 minutes. The
data are processed by statistical analysis. Three significant latent factors for the variations of the
variables were determined by factor analysis. Control graphs and histograms show that the quality
parameters - tablet strength, drug dissolution after 150 minutes and drug dissolution after 165
minutes - are not under statistical control as there are points outside the control limits. Action
needs to be taken to address the specific causes of these variations.

Other areas

Energy efficiency and renewable energy sources

The use of non-traditional energy sources and the improvement of energy efficiency
among energy consumers is a global trend imposed by the limited fossil energy resources and the
growth of the amount of energy consumed. Bulgaria has the potential for the development of
renewable energy sources, but the sharp increase in operating capacity, with a high price of
energy produced and low incomes of the population, have led to problems. Moreover, Bulgaria is
the most inefficient energy user in the European Union, which deepens the problems with the
economic stability of the Bulgarian energy sector. The state and trends of development of various
renewable sources and promising technologies for solar energy conversion are discussed. It is
shown that after reaching the planned share of renewable sources in Bulgaria in 2020, instabilities
will appear in our energy system, which requires from now on to begin the completion and
improvement of the energy system under the concept of smart grid. Data on energy production
and consumption, the energy efficiency of homes, and some leading energy-intensive
technologies in the industry are also provided.

The publications related to the topic of new materials and technologies for renewable
energy sources analyze the trends and problems, discuss new solutions and approaches in
solving the practical problems of future energy technologies.

Ergonomic quality of e-learning

A study of the ergonomic quality of e-learning was made, measured by defining the
following criteria: efficiency, effectiveness, and satisfaction with e-learning and its implementation,
based on a survey and the opinion of both teachers and students. The score obtained is not low,
according to the methodology used, but serious work needs to be done on the satisfaction criterion
for both groups. Lower values of the satisfaction criterion were obtained, however, they were compensated by the high evaluations for efficiency, which was highly evaluated by both groups.

The results of the survey were analyzed by factor analysis, which confirmed the grouping of questions in different categories. Problems are defined, dependencies are analyzed and possible solutions are suggested.

**Event management system**

The challenge for managing events such as scientific conferences and other seminars organized each year around the world is to provide an improved (easier) way to implement the process for both participants and organizers. One of the most promising approaches in the quality improvement of an information system is the Model-Driven Development (MDD). It implements models at different levels of abstraction and applies the model transformation into a generated code. The main objective of this paper is to present an approach for model-driven development of an event management system based on UML. The main requirements and data model of the system are modelled with UML use case diagrams, class diagrams, and activity diagrams to achieve portable and reusable models of the system. The conceptual data model is implemented in a MySQL based database.