NATIONAL CENTRE FOR INFORMATION AND DOCUMENTATION

# ADVANCES
# IN
# BULGARIAN SCIENCE

1 2006
SOFIA

Published by National Centre for Information and Documentation
52 A G. M. Dimitriv Blvd
1125 Sofia, Bulgaria,
Phone: +359 2 817 38 62
*http: www.nacid-bg.net*
e-mail**:** advances@nacid-bg.net



Disclaimer
The articles are published as provided by their authors, without additional editing.

ISSN: 1312-6164

# NATIONAL RESEARCH PROGRAM "NEW TECHNOLOGIES IN POWER ENGINEERING"

*Power engineering is the basic element in almost all sectors of national economy in modern societies entirely depending on permanent energy supplies to maintain their quality of life. Energy demands will quickly increase in the future owing to industry needs and modern energy-consuming technologies in everyday life.*

*Sustainable energy sources of the future should have the following basic qualities: they shouldn't create greenhouse effect in order not to pollute the environment and shouldn't consume unrecoverable natural resources. Only two energy sources are in keeping with these conditions: thermonuclear fusion and hydrogen. Hydrogen remains the main energy source of the future because of serious problems connected with thermonuclear fusion control. Solar thermal generators, hydroelectric power stations, solar cells, biomass, wind generators, and tidal power are other feasible sustainable energy sources. But unlike hydrogen they cannot be used permanently. Hydrogen may be used for various energy needs, even for electric power production. The use of hydrogen fuel cells for driving cars is an important application that will lead to ecological comfort through reduction of greenhouse gas emissions. Hydrogen may be produced not only by electric way, but also from biomass – from plants and daily wastes.*

*"New Technologies in Power Engineering" program is in conformity with the long-term prognostications on development of economy, science, social life and inclusion of research teams into the European Research Area.*

*Research, educational and production units conducting investigations of new technologies in the field of power engineering exist traditionally in Bulgaria. These investigations are directly connected with European research programs and world trends in this sphere. Priorities of the program are as follows:*

- *Development of fuel cells for hydrogen and other gases;*
- *Development of new technologies for production of heat and electric power from biomass;*
- *Development of new technologies for production of solar, heat and electric power;*
- *Development of new technologies for radioactive wastes processing and preservation.*

*Through development of the tasks the program aims at:*

- *Higher competitive power of the research and technological potential of the country and improvement of the quality of life through introduction of new technologies in power engineering;*
- *Creation of favourable conditions for development of national infrastructure in the field of power engineering;*
- *Integration of Bulgaria with the European community as an equal and sought partner in the sphere of development and introduction of new technologies in power engineering.*

# NACID

## National Centre for Information and Documentation

**MAIN OBJECTIVES**

- NACID is a governmental institution affiliated to the Ministry of Education and Science. NACID collects, processes, maintains and disseminates reference and analytical information to support the national policy in the field of education, science and innovation as well as to support Bulgarian research bodies, individual researchers and SMEs

**PRIMARY FIELDS OF ACTIVITIES:**

- Processing and disseminating bibliographic, reference data and analytical information.
- Maintaining specialized databases of scientific production and research resources in Bulgaria.
- Providing information about national, European and trans-European research programs.
- Providing information to support the process of harmonization of the Bulgarian education and research legislation with European Union ones.
- Performing the role of institutional contact point of the Sixth Framework Program in Bulgaria.

**INFORMATION PRODUCTS AND SERVICES**

- NACID offers a large range of information products, including:
  - Subject profiles;
  - Reviews;
  - Bibliographic references;
- NACID offers a great variety of information services through its own databases as well as information brokerage to external databases to the following locally maintained own databases:

**„Bulgarian Science“ Databases**

- *„SIRENA“,* R&D reports and dissertations; more than 80 000 records
- *„Scientific and Technical Publications in Bulgaria“,* more than 2500 records.
- *„Who is Who in Bulgarian Science“*- more than 5 500 records.
- *„Papers“,* Number of records: 118

**„Science and Industry“ Databases**

- *„Partnership for Innovation and Development“.* Information about the national Research units.
- *„Knowledge for Innovations and Development“* Information about Bulgarian R&D activities.

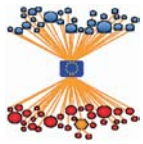
*The information brokerage* services are available upon request, providing access to over 1200 databases from major international commercial host centers, thus providing the research community with a wealth of S&T information.

- *Central Research and Technical Library* services:
  - Library collections - more than 4 million items/reference books, monographs, serials, dissertations, CD ROM, DVD etc.,
  - Online access to the library catalogues since 1980;
  - Searching in electronic catalogues and databases;
  - Lending of library materials;
  - Electronic Document Delivery;
  - Interlibrary loan;
  - More that 9000 users per year.

# CONTENTS











# NATIONAL SCIENTIFIC PROGRAMMES WITH EUROPEAN DIMENSIONS

## SOME POSSIBILITIES FOR SIGNIFICANT INCREASE OF ENERGY EFFICIENCY BY PRODUCTION OF HEAT AND ELECTRICAL ENERGY

**Prof. Nikolai Kolev, DSc; Dimitar Kolev, PhD;**
Laboratory "Heat and mass transfer processes in gas-liquid system",
Istitute of Chemical Engineering, BAS
Acad.G.Bonchev str., Bl.103, 1113 Sofia, Bulgaria,
*Phone: (+359 2) 870 40 19; (+359 2) 979 32 81, E-mail: kolev@bas.bg*

**Introduction**

One of the biggest problems facing mankind is the problem of reduction of emissions of green house gases with simultaneous increase of production of heat and electrical energy. An important step in this direction is the increase of energy efficiency of industrial processes. In this paper short information on investigations carried out in the laboratory "Heat and mass transfer processes in gas-liquid system" at the Institute of Chemical Engineering of the Bulgarian Academy of Sciences is presented. The investigations include creation of new processes with higher efficiency and new apparatuses for these processes. Some of the investigations are carried out together with partners from Bulgaria and abroad. Three main directions for solving the problem are investigated.

1. Utilization of waste heat of flue gases from boilers mainly for district heating purposes.

2. Reduction of energy consumption for drying at simultaneous utilization of heat of flue gases.

3. Increase of energy efficiency of gas turbine cycles.

As a result of the investigated possibilities, 11 installations for three types of different processes are already implemented in the industry. Two types can be implemented after finding investors and one is in a stage of thermodynamic investigations.

In this paper short information about the results of these investigations is presented.

**1. Utilization of waste heat of flue gases from boilers for district heating purposes.**

In the first generation systems of contact economizers [1] waste heat of flue gases from boilers of power (district heating) stations, which burn natural gas, is utilized for heating the feed water for the boilers and for the district heating nets. The technological scheme includes a packed bed column (contact economizer). In its packing the gases are washed with circulating water in countercurrent. The heated circulation water is cooled in a modern plate heat exchanger, where pure water is heated. The principle of these installations was well known before our investigations. The insurance of uniform distribution of the phases over the apparatus cross section, using new patented constructions and additional intensification of the heat and mass transfer processes in the packing, gave possibility of significant reduction of capital investments for such installations. Their great advantage is that they utilize also condensation heat of water vapor in the flue gases. It is well known that by burning of 1 kg natural gas (methane) 2.25 kg water vapor is obtained. That is why cooling

the flue gases from the temperature of 120°C to about 30°C it is possible to utilize heat equal to about 12-13% of the heat obtained in the boiler. The pay back term of the new installations is about 6500 hours of operation time, i.e. less than one year.

Like any technical solution, the first generation of contact economizer systems has its advantages and shortcomings. The disadvantage is connected with the fact that the amount of the feed water in the respective power stations is very small to utilize by this technology all the waste heat of the flue gases. Two solutions for elimination of this shortcoming are investigated in the laboratory: creation of a special lamella type heat exchanger [2, 3] instead of the first generation contact economizers and creation of the second generation contact economizer systems.

**1.1. Creation of a special lamella type heat exchanger**

The results of mathematical modeling [3] of the new construction of a lamella type heat exchanger show that the end temperature of the heated pure water is significantly higher than in the first generation of contact economizers, which allows to utilize more waste heat with a given quantity of feed water. At the same time the dimensions of these installations are smaller and the pay back term is with about 25-30 % lower. The weight of the apparatus for utilizing of 1 MW waste heat is about 600 kg at pressure drop for the gas phase about 3.6 kPa [3]. In spite of its better operating parameters, this heat exchanger cannot utilize all the waste heat of the flue gases for heating of cold streams in power stations. This, in case of district heating stations, can be done with the second generation of contact economizers.

**1. 2. Second generation contact economizer systems**

District heating systems are the greatest consumers of low potential heat. Their circulation water comes back in the station with temperature about 45-55°C to be heated in the boilers. Contact economizers of the first generation are not appropriate to heat this water because the bulb temperature of the flue gases, which limits the temperature of the heated water, is only 60°C. Loosing 1°C in the contact economizer and 3°C in the heat exchanger, it is practically impossible to utilize significant part of the condensation heat of water vapors to heat this water and just this heat is more than 2/3 of the waste heat of the flue gases. To solve the problem, a second generation contact economizer system is created [4]. The essence of the idea is to humidify the air entering the boiler burner, using waste heat, and in this way to increase significantly the bulb temperature of the flue gases. Technological scheme of the installation is presented in Fig. 1.

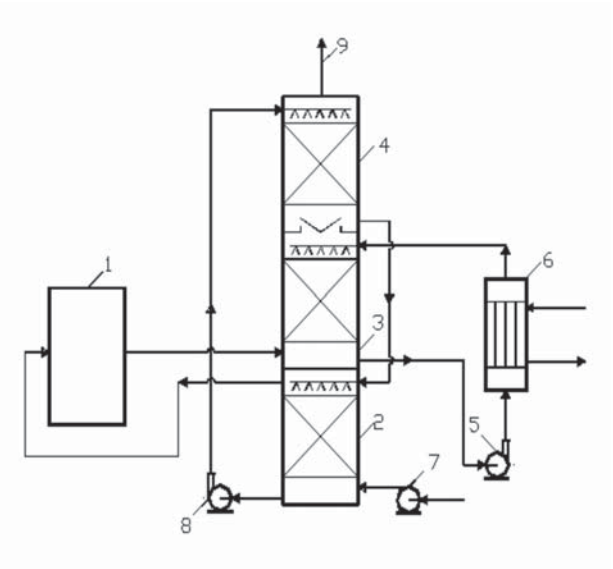



Fig. 1. Technological scheme of a second generation contact economizer system.

The flue gas from the boiler 1 enters the bottom part of the first contact economizer 3 of the combined apparatus. Here it is treated with circulation water from the heat exchanger 6, where the district heating net water, coming from the town, is heated. The warmed water after additional heating with hot waste heat enters the district heating net. The heated circulation water from the contact economizer 3 through the pump 5 enters the heat exchanger 6. The preliminarily cooled flue gas is additionally cooled in the second contact economizer 4 heating the second flow of circulating water. In the packing of the column 2 this second flow heats and humidifies the air from the ventilator 7 before it enters the burner of the boiler 1.

A pipeline with valve mounted parallel to

the installation before the ventilator 6 gives possibility to regulate the gas flow in the economizer.

This humidifying of the flue gas has two positive effects:

1. It increases the bulb temperature of the flue gases, which ensures the same efficiency of the second generation contact economizer system as that of the first generation, i.e. utilizing heat equal to about 12-13% of the heat produced in the respective boiler, but at higher temperature level.

2. It reduces the flame temperature, which leads to about 3.8-time reduction of NOx emissions. The emission of $CO_2$ is reduced with 12-13% due to increase of the energy efficiency. Because of the water vapor concentration increase in the flame and as from all components of the flue gas only three atom molecules, these of water and of $CO_2$, radiate heat, the end temperature of the flue gases remain practically constant, not increasing with reduction of the flame temperature. In Fig. 2 the photograph of two contact economizers built in a district heating station in Plovdiv, Bulgaria is presented.

**2. Reduction of drying installations energy consumption at simultaneous utilization of the heat of flue gases.**

Drying installations are one of the greatest heat consumers. Usually drying is performed by means of flue gases. The heat used in this case is transformed mainly to heat of water evaporation, which can be utilized by means of first generation contact economizer systems. In our investigations modern spray dryers for ceramic suspension are considered. The suspension, with concentration of about 50%, is dispersed in the apparatus through many nozzles. The drying agent, a mixture of flue gases and air, with temperature 450-550°C, enters the upper part of the apparatus. The initial temperature of drying is connected with the material properties, which do not permit significant increase of temperature. The obtained dry product falls in the conic bottom of the apparatus and exits through a special device. The fine dust separated in cyclones, exits the installation through the same type of devices. The flue gases with temperature 100-115°C, containing about 22 % vol. water vapor, exit the installation through a ventilator. The fuel is natural gas. In the above-mentioned case the flue gas bulb temperature is about 63-64°C. That is why even if a good contact economizer system is used, the temperature of the heated pure water is only 58-59°C. A flow with such temperature cannot be used for warming of plant halls, the only consumer of waste heat near the dryer. It is because the hall heating system is designed to operate with steam or water with higher temperature. The increase of temperature of the utilized heat is possible by rising of the water vapor concentration in the flue gases after the dryer, which leads to increase of the bulb temperature. It is easy to be done, if flue gases taken after the dryer are used instead of additional air. Apriori this means to input additional heat in the dryer, which, if it is possible, leads to increase of energy efficiency of the process. Naturally, to keep the rate of the drying process and humidity of the dried material constant, the end temperature of flue gases after the dryer must be higher which leads to reduction of energy efficiency of the installation. Special mathematical model is developed to predict complexly the effect of recirculation on the energy efficiency of drying. Based on the good result from the modeling, the installation is reconstructed. Its technological scheme after reconstruction is presented in Fig. 3.

The installation operates as follows: Air trough the ventilator 1, natural gas as fuel through pipe 3, and re-circulated flue gases through the ventilator 18 are fed into the burning chamber. The flue gases with temperature 450-550°C enter the dryer 6. The pipeline 5 feeds there the ceramic suspension. The suspension is sprayed by the nozzles of the distributor 7 and dries, contacting with the hot flue gases. The dried material in the form of powder settles in the cone bottom of the dryer. Small part of it, retained by the flue gases, is separated in the cyclone 10.

The obtained dried product leaves the dryer through a special device mounted at the upper parts of the lines 8 and 9. After the cyclone the flue gases are divided into two flows. One of them exits the installation through the ventilator 11 and the chimney. The other is fed

Fig. 2. Second generation contact economizers in the district heating station Plovdiv South.

into the burning chamber through the ventilator 18 and the duct 2. At closed valve 12, the flue gases enter the contact economizer 14 through the duct 13. Here they are scrubbed and cooled with cold circulating water. During the cooling great part of the water vapor condenses, and great part of the dust is separated, too. The condensate containing the separated dust exits the installation by the hydro-locking device 17 and can be used for preparation of ceramic suspension before its drying. This results in utilization not only of the condensed water, but also of its heat.

The circulated water warmed in the packing 16 of the contact economizer 14 enters the heat exchanger 20 by pump 19. Here it warms the pure water flow with an initial temperature of about 55°C, entering the apparatus by the pipeline 22. The pure water heated to about 75°C leaves the heat exchanger 20 through the pipeline 23. The circulated water cooled in the heat exchanger 20 enters the contact economizer by pipeline 21, and by distributor 15 it is spread equally over the cross section of the economizer packing.

The obtained results are presented in table 1. It is seen that after the reconstruction the fuel consumption for drying is reduced with 15.65%. At the same time in the contact economizer 16 about 1.6 MW waste heat can be utilized. Because of lack of heat consumers, it was decided to design a contact economizer system for the necessary 1 MW.

**3. Increases of energy efficiency of gas turbine cycles.**

It is well known that gas turbines are one of the best types of machines for transformation of chemical energy of the fuel to mechanical energy. Their main disadvantage is that they need great excess of air, over the stoichiometric amount, necessary to reduce the temperature of the flue gases leaving the combustion chamber. In order to ensure this excess, 50 to 66% of mechanical energy produced by the turbine is consumed by the air compressor. This leads to decreasing of thermodynamic efficiency of these machines, which is about 38.5%. To eliminate this shortcoming, two types of investigations are carried out in the laboratory. The first of them is ready to

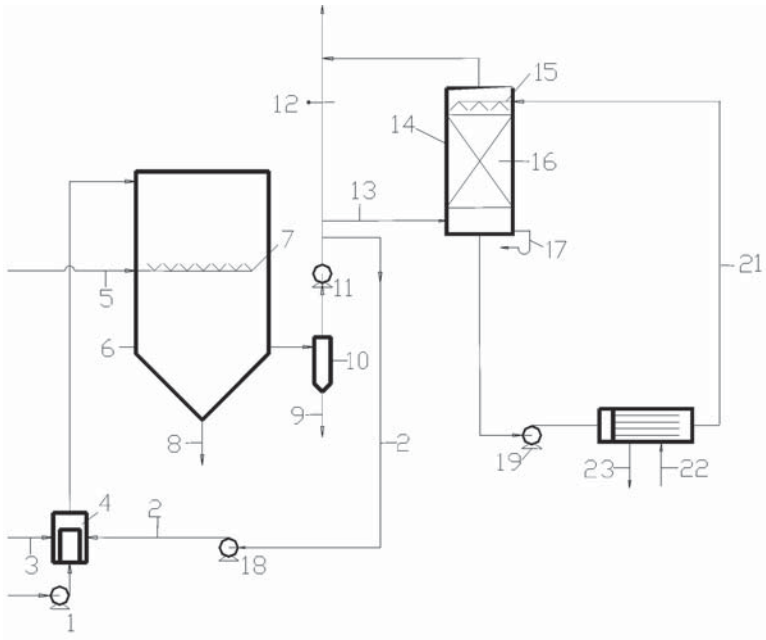



Fig. 3. Technological scheme of the reconstructed installation.

be implemented in the industry, needing only the respective industrial installations to be designed. The investigation of the second one is just beginning.

**3.1. Increases of energy efficiency of the gas turbine by replacing the overstoichiometric air with steam**

Table 1. Experimental data for the reconstructed installation.

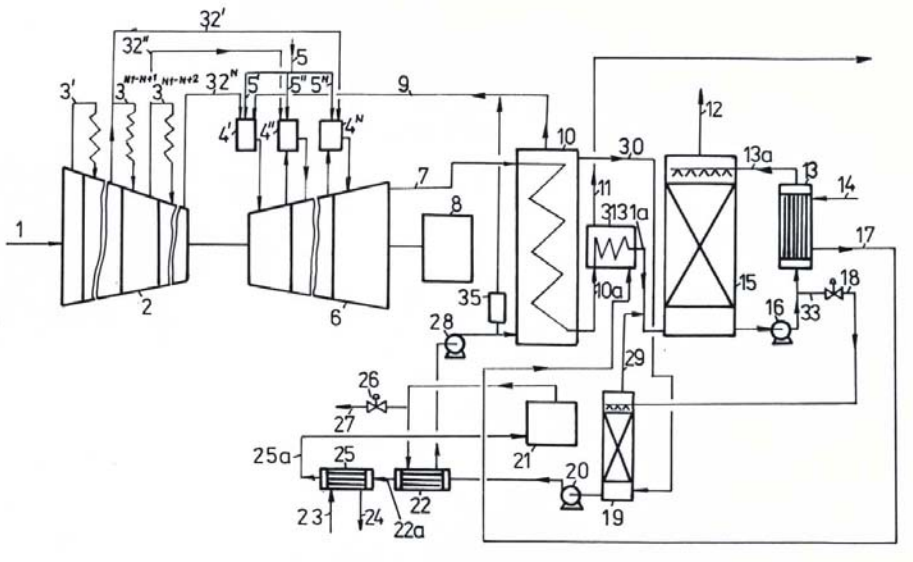
| | Dimension | Without recirculation | With recirculation |
|---|---|---|---|
| Absolute pressure | **kPa** | 98.7 | 98.7 |
| Productivity ,dried material | **ton/h** | 4.00 | 4.00 |
| Initial flue gas temperature | **°C** | 513 | 482 |
| Exit flue gas temperature | **°C** | 111 | 122 |
| Exit flue gas bulb temperature | **°C** | 63.8 | 82.7 |
| Exit flue gas humidity | **vol. %** | 22 | 52 |
| Humidity of the dried ceramic material | **%** | 6 | 5.6 |
| Reduction of fuel consumption due to recirculation | **%** | - | 15.65 |

According to the first technology [8, 9], practically the whole quantity of the overstoichiometric air is replaced by steam. The necessary steam is produced in a boiler, where the flue gas after the turbine is cooled to a temperature of about 120°C. According to the new method, the flue gases after the boiler are cooled additionally in a system with a contact economizer to a temperature of about 50°C. At these conditions, not only the whole quantity of the steam passes to the gas turbine combustion chamber, but also a great part of the water, obtained in burning of the fuel, is condensed and can be easy transformed in feed water. The utilized heat is used for district heating purpose. For this reason, the new installation is especially proper to be used as a part of a district heating system. The idea to reduce the energy for the compressor using steam instead of a part of the overstoichiometric air, and in this way to increase the energy efficiency of the installation, is offered by Cheng and is well known for many years. Its limited use up to now is owing to loosing of the pure water from the steam as water vapor with the flue gases [10]. Technological scheme of the new installation [8, 9] is presented in Fig. 4. The air required for burning of the fuel enters the turbocompressor block 2through the pipe 1. The compressor is divided into N stages. Heat exchangers 3, respectively 3' to $3^{N1-1}$, are connected between the stages of the compressor in order to reduce the energy needed for the compression. In the case of district heating plants, it is possible to cool these heat exchangers by means of the cooled district heating network water, increasing the overall thermodynamic efficiency of the installation. This fact, and especially condensation of part of the water vapors obtained from fuel burning, permits the coefficient of thermodynamic efficiency for these installations to be higher than 100%, if the efficiency is calculated, as usual, with the lower calorific effect of the fuel. The air from the compressor block enters the combustors 4, respectively 4' to $4^{N}$ of gas-steam turbine 6, along with the fuel, e.g. natural gas and flue gases cooled in the previous stages of the turbine. Steam is also added to combustor 4'. Mechanical energy produced in the turbine moves the electric generator 8 and the compressor block 2. After the turbine, the gas-steam mixture enters boiler 10, where it is cooled, and then the heat exchanger 31 with ribbed pipes. The gas-steam mixture cooled to about 100°C enters the contact economizer 15, after which the finally cooled flue gases, with a temperature of about 50°C, are thrown out into the atmosphere by means of the stack 12. The flue gases are cooled in the contact economizer by circulating water passing through the heat exchanger block 13 by means of the pump 16. The block 13 is cooled by district heating network

water entering through the pipe 14 and leaving from the pipe 17. The obtained water condensate is passing through the valve 18, which controls the water level in the economizer. Then the condensate enters the packed bed column 19 for removal of carbon dioxide and oxygen. The column is operating with steam coming from boiler 10 through line 30. The gas-steam mixture obtained in column 19 passes through pipe 29 and is mixed with the flue gases before their entry into the contact economizer 15. The condensate treated in the column 19 enters heat exchangers 22 and 25 by means of the pump 20 and is cooled to the operating temperature of the ion exchanger block 21. After this block, water is heated again in heat exchanger 22, cooling the hot water condensate. The heated water enters the boiler 10 to evaporate and become overheated. The overheated steam enters combustor 4. If the heat of the gas-steam mixture is not enough, boiler 35, which could be heated by coal burning, is also connected in order to provide the required steam.

Thermodynamic efficiency of the new installation [11, 12] is investigated together with Prof. Schaber, from the Technical University – Karlsruhe, for burning of methane in a wide range of initial pressures, up to 300 bars, initial temperatures and number of stages of the turbine. Some of the obtained data are presented in Fig. 5.

The results show that mechanical efficiency reaches up to 63 % at 300 bars. Up to now the highest pressure of gas turbines is 50 bars. Investigations show that at this pressure even at 2-stage turbine which already exists, mechanical efficiency is about 53%, i.e. it is significantly higher than this of the existing gas turbines. The possibility for operation without overstoichiometric quantity of oxygen makes the flue gases from this cycle practically free from $NO_x$. Calculations show also that for compara-




(1) air inlet; (2) turbocompressor; (3) 3′ to $3^{N1-1}$ heat exchangers for air cooling; (4) 4′ to $4^{N}$ combustion chambers; (5) 5′ to $5^{N}$ lines for fuel passing; (6) gas-steam turbine; (8) electric generator; (10) boiler-utilizer; (11) pipe for final heating of district heating water; (12) outlet of flue gases to the chimney; (13) heat exchanger block; (14) and (17) inlet and outlet of district heating water to the heat exchanger block; (15) contact economizer; (16) circulating pump; (18) regulating valve; (19) packed bed column for removal of carbon dioxide and oxygen from condensate; (20) and (28) pumps; (21) ion exchange block for chemical purification of condensate; (22) and (25) heat exchangers; (23) and (24) pipes for inlet and outlet of cooling water from exchangers (25), (26) and (27) regulating valve and pipe for removal of chemically purified water in the installation; (31) head exchanger with ribbed pipes for additional heating of district heating water; (35) boiler.

Fig. 4. Technological scheme of the installation with gas-steam turbine

ble electrical energy production the turbine is about 2.35 times smaller, or at the same dimensions it can produce 2.35 times more electrical energy. The compressor is 7.3 times smaller. The investigations are ready to be implemented in the power stations using a combination of existing turbines, compressors and electric generators, and a special design of a contact economizer system, using our experience.

**3.2. New gas steam turbine operating after the Carnot cycle.**

From energy efficiency point of view the

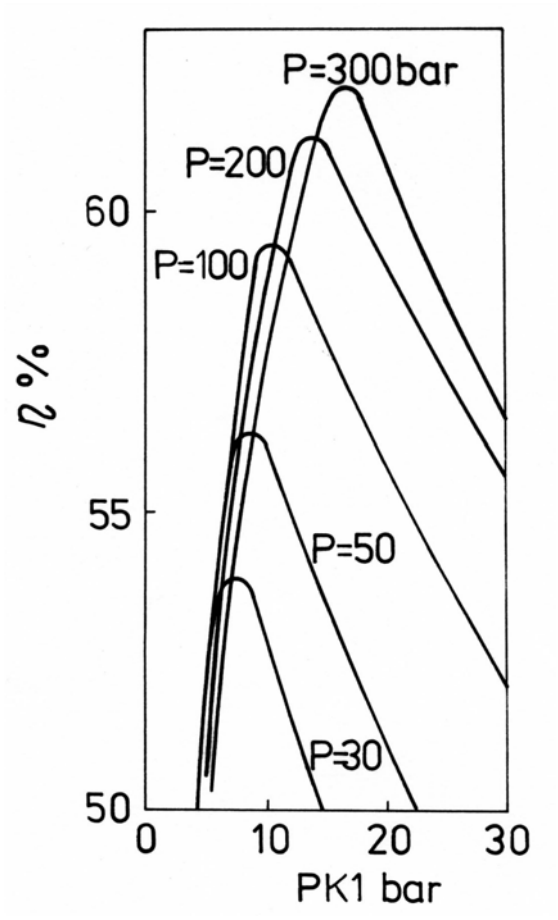



Fig. 5. Mechanical efficiency of a 6 stage turbine versus the initial pressure in the last stage of the turbine PK1 at coefficient of air excess equal to 1, at initial calculation temperature equal to 1200°C.

Carnot cycle is the best thermodynamic cycle for transforming heat in mechanical energy. Nevertheless, up to now no industrial installation operates after this cycle. According to the cycle, the operating gas in the machine is expanded in two steps, first isothermal, by additional heating, and second – adiabatic. In the existing turbines only adiabatic expansion is used. The invention [13] is explained in short below.

As it was already mentioned, great problem of the existing gas turbines is how to operate in order to reduce the inlet temperature of flue gases to temperature at which the material of the turbine is stable. Up to now the following possibilities are used:

1. Great amount of overstoichiometric air.
2. Replacing the overstoichiometric air or part of it with steam.
3. Injection of water.

Another more simple method for reduction of the initial gas temperature, not proposed up to now, except in [13] and [14], is based on the fact that when feeding oxygen (air) and methane in the burning chamber, not only exothermic but also endothermic chemical reactions are possible. The reactions are as follows [15]:

$CH_4 + 2O_2 = CO_2 + 2H_2O + 803712$ kJ/kgmol methane (1)

$CH_4 + 0{,}5O_2 = CO + 2H_2 + 35590$ kJ/kmol methane (2)

$CH_4 + H_2O = CO + H_2 - 206410$ kJ/kmol methane (3)

$CH_4 + CO_2 = 2CO + 2H_2 - 2482800$ kJ/kmol methane (4)

Calorific effects of the reactions show that when operating with lack of oxygen, it is possible to control the temperature after the burning chamber in order to keep it not higher than the turbine material can endure. In this case part of the fuel is transformed into CO and $H_2$. The process is called conversion and is well known in the chemical industry for production of technological gases for synthesis of ammonia, methanol and other products [15].

Similar reactions are possible with other hydrocarbons used as fuel in gas turbines.

If the gases uses for cooling of the turbine internals contain oxygen and if its amount is regulated along the turbine in order to keep constant temperature up to full consumption of CO and $H_2$, it is possible to keep isothermal expansion of gases, i.e. to ensure the firs part of the Carnot cycle. After it the expansion of gases will be adiabatic.

The control of the oxygen distribution along the turbine in order to ensure isothermal process is possible by proper dimensioning of the channels for cooling the internals and, if necessary, by mixing the oxygen, or air, with steam.

Other important problem to solve before

designing the new turbine is connected in principle with possibility of building of soot at lack of oxygen after the endothermic reaction:

$$CH_4 = C + 2H_2 \quad (5)$$

It is well known that at proper amount of steam in the gases no soot is built because it is transformed into CO and $H_2$ according to the reaction:

$$C + 2H_2O = CO + 2H_2 \quad (6)$$

Great problem of the existing gas turbine is the emission of NO obtained by $O_2$ excess and presence of $N_2$ according to the reaction:

$$N_2 + O_2 = 2NO \quad (7)$$

The reaction is endothermic and that is why it is passing only at high temperatures. That is why to eliminate it it is necessary to feed the air excess used for full burning of the rest of CO and $H_2$ at temperatures of about 850°C at which the effect of the reaction (7) can be neglected.

Strong cooling of the burning chamber because of the endothermic reaction (3) and (4) gives in principle possibility to use pure oxygen, instead of air, and to obtain pure $CO_2$ after cooling the flue gases in the contact economizer, analogously to pos. 15 in Fig. 4. It is to be expected that the use of pure oxygen leads to additional increase of efficiency of the installation. The obtained $CO_2$ can be injected in the oil-fields to increase the oil production.

Knowing that from thermodynamic point of view the Carnot cycle is the best for transforming the heat energy, respectively chemical energy of the fuel into mechanical one, and in this way into electrical energy, it is sure that the new turbine cycle is the best from economical and ecological point of view. The first step of the investigation is thermodynamic determination of the optimal conditions of the process with burning using air or pure oxygen and the optimal content of steam to prevent building of soot as a function of temperature and pressure. According to the contract with the National Science Fund of Bulgaria, the investigation will be carried out by scientists from the Institute of Chemical Engineering of the Bulgarian Academy of Sciences, Technical University – Sofia and the University of Chemical Technology and Metallurgy – Sofia. The project is open for all specialists in the area of gas turbine construction who can help to implement the new invention in the industry.

References:


1. Kolev N., R. Darakchiev, Kr. Semkov. Systems Containing Contact Economizers for Flue Gas Heat Utilization. *Energy Efficiency in Process Technology*, Vouliagmeni (Athens), Greece, 19-22.10.1992, Commission of the European Communities.

2. D. Kolev. Heat exchanger for utilization of the heat of flue gases. Bulgarian patent BG 64570 B-1, 14.09.2001 (in Bulgarian).

3. Kolev D., N. Kolev. Performance characteristics of a new type of lamella heat exchanger for utilization of the flue gases heat. *Applied Thermal Engineering,* 22(2002) 1919-1930.

4. N. Kolev, A. Mirchev, Kr. Semkov, R. Daraktshiev. Method and device for treating of flue gases from burning processes, Reg. No. 77784 / 28.12.1986.

5. N. Kolev, D. Kolev. Drying installation for production of powder material. Bulgarian patent, Reg. No 103072, 11.01.99 (in Bulgarian).

6. D. Kolev, N. Kolev. New Technology for Utilization of Waste Heat of Flue Gases from Drier Installations. Sixth Bulgarian–Hungarian Workshop, Chemical Engineering, Proceedings, Sofia, 2000, pp 23-30.

7. D. Kolev, N. Kolev. New technology for utilization of the waste heat of flue gases from dryer units. *Bulgarian Chemical Communications*, 32, Nr. 3-4(2001) 485-495.

8. N. Kolev, D. Kolev, N. Filipova. A method and an installation with a gas-steam turbine for heat utilization at burning of gas and liquid fuels. Bulg. Patent. No BG 62982 B1/18.02.1997 (in Bulgarian).

9. N. Kolev, D. Kolev, N. Filipova. A method and an installation with steam-gas turbine for heat utilization at burning of gas and liquid fuels. Bulg. Patent No BG 63223 B1/12.01.1998 (in Bulgarian).

10. M. Perkavec. Gasturbienen. BFK 49 (4) (1997) 97-103.

11. N. Kolev, K. Schaber, D. Kolev. A new type of a gas-steam turbine cycle with increased efficiency. *Applied Thermal Engineering,* 21 (4) (2001) 391-405.

12. N. Kolev N., K. Schaber, D. Kolev. A new type of gas-steam turbine cycle. Proceedings of the First International Conference on Industrial Gas Turbine Technologies, 10-11th July 2003, Brussels. Edited by D. Polard and P. P. Pilavachi.

13. D. Kolev, N. Kolev. Method and installation for increasing of the efficiency of gas steam turbine at simultaneous production of mechanical energy and heat. Application for Bulgarian patent, Reg. No 108378/ 234.11.2003.

14. N. Kolev, D. Popov, D. Kolev. New type of gas turbine cycle, preliminary investigations. Second International Conference on Industrial Gas Turbine Technologies, 28-29 April, 2004, Bled, Slovenia.

15. Sprawochnik azotchika (References book of nitrogen compounds production). Chemistry, Moscow, 1967 (in Russian).

# DEVELOPMENT OF NEW TECHNOLOGIES FOR PRODUCTION OF HEAT AND ELECTRIC POWER FROM ORGANIC WASTES FOR INCREASING THE ECONOMIC EFFICIENCY OF THE FINAL PRODUCTS

**Assoc. Prof. Ivan Simeonov, PhD;** Institute of Microbiology "St. Angelov", BAS
**Assoc. Prof. Dencho Denchev, PhD;** "Prof. A. Zlatarov" University, Burgas
**Prof. Bayko Baykov, DSc;** Science Research Institute of Ecology, New Bulgarian University

## I. PRECEDING RESEARCH ANALYSIS OF THE PROBLEM

The anaerobic digestion (AD) of organic wastes (also known as methane fermentation) is a biotechnology that mineralizes different in origin organic wastes and as a result compost (manure) and biogas (energy source) are produced [1-5]. Methane fermentation kills all the pathogenic microorganisms and the eggs of helminthes, on the other hand bad odor and toxic organic wastes convert to non-toxic substrates. The increased interest of many European countries in this biotechnology is due to the following advantages: 1. It solves **energy problems**; 2. It solves **environmental problems**; 3. The compost is natural manure replacing the high energy consuming fertilizers and it can be used in **ecological agriculture**.

Though there are 15 million biogas plants working in the world, former Bulgarian and other European countries' experience shows that it is not possible to mechanically apply the experience of different countries in biogas production from organic wastes. So far in our country millions of levs have been spent for building experimental biogas plants (Podgumer village – Sofia region; Biala Rada village – Vidin region, Vraca –town) [6], but due to no preceding research they didn't work efficiently. The experience in other countries is the same.

This necessitates the development of new more efficient and stable technologies for biogas production from organic wastes as well as the appropriate equipment – bioreactors and sensors for process control purposes and new methods and algorithms for its optimization and control.

Every three years, for Europe - every year, congresses on AD and biogas technologies are organized. Despite the great success now, there are a lot of problems waiting for a solution: 1) Often unexpected failure of the process couldn't be avoided, 2) Energy efficiency is not enough, 3) Waste water treatment is not efficient for the direct utilization of water from biogas plants. These are the reasons for the great intensification of scientific research in this area – microbiological, biochemical and related to the optimization of the methane fermentation process - for the development of specific biogas production biotechnologies according to the characteristics of the resource, its quantity and the specific objectives (ecological and energetic), keeping in mind the Bulgarian conditions.

The terms "modulation" and "modulator" are used in ecological biotechnology. The first one defines some changes in the biodegradation parameter, and respectively it is related to the degradation rate of xenobiotics. The second term is a derivative concept of modulation. It concerns factors and/or substances that change some of the components of the system, being present in it as well as the processes taking place. The problem of interactions between heavy metals and microbial cells provokes interest according to a number of practical problems as well as from theoretical point of view. Practical interest is due to the fact that these elements are among the main contaminators of soil and waters. On the other hand their toxic effect on microorganisms, plants and humans is well known. Heavy metal compounds are widely used as bactericides and fungicides and residual quantities of them go to the food of animals, and after that into the de-

rivative products. Ions of heavy metals pass to the substrates undergoing anaerobic digestion in different ways. The first way is through animal food, the second - through the waste waters from different manufactures, the third - depends on the specific processes of digestion of the substrate. Their characteristics and concentration are not stable and vary in different ranges. Very often these parameters change in pulsations. That is why methane fermentation is difficult to predict concerning the inhibitory effect of metal ions.

Microbial cells reactions observed by different authors correlate to inhibition of growth. Morphology and ultra structural changes were noticed, changes in cell metabolism and enzyme activity. Along with the inhibitory effect of heavy metals on microbial growth, we observed reactions of adaptation to them. Some of the microbial species are able to adapt and to grow under high concentrations of metal ions. Besides the direct effects heavy metals can also affect the physical and chemical parameters of the process. All these phenomena were well studied in vitro, in isolated solutions and media. The effect of heavy metals on microbial cells during the anerobic processes are not studied well. There is lack of published data concerning different microorganism reactions taking part in the different stages of AD. It is due to the complicated and changing composition of the microbial society, as well as to difficulties of isolation of specific microbial species. It was shown that ions of the metals Cu, Cr, Cd, Zn, Ni and Pb inhibit assimilation of acetic acid, propionic acid and butylic acid, products of acetogenesis of organic wastes, thus delaying or stopping AD. Ion effect depends on the nature of the metal, the sort of the organic substrate, the kind of the fatty acids produced in the acidogenesis and on the time of action. All these conclusions were made studying experimental "model mixture" of the above mentioned substrates. The inhibitors affected microorganisms in the first stage of the process or the acidogenesis in any studied case. There is no information about the methane bacteria. Detoxication of metal ions through their accumulation in microbial cells was observed simultaneously. However, the process is possible, even though it slowed down.

The application of chemicals in agriculture started in the 20$^{th}$ century by using biocides and fertilizers. According to FAO (2001), the production of fertilizers is one of the highest energy consuming industries. It is well known that maximum 20% of the fertilizers are used by plants; the other 80% contaminate underground waters and soil. The problem is not only ecological but also concerning energy: the inefficient utilization of fertilizers means that the energy consumed for their production is 5 times higher. Fertilizers usually contain only macroelements; however biogenic microelements are the limiting factor in agroecological systems.

The alternatives of fertilizers are farm wastes, which according to the information of the Ministry of Environment and Waters (2003), are not used efficiently in Bulgaria. That is why they are contaminator No 2 of our environment. The degree of utilization of farm wastes is 2.91%, which is the reason for accumulation of 107.18 million tons liquid organic wastes and 19.56 million tons solid wastes each year.

The AD is a possibility for utilization of biomass, i.e. organic wastes from farming and food industry for the production of biogas and compost – a product containing biogenic macro- and microelements in optimal proportions necessary for plants. Science research on compost is interesting not only for conventional production in agroecological systems (for saving energy), but also for organic plant production (ecological agriculture), where fertilizers are not allowed. Ordinances № 22/2001 and № 35/2001 of the Ministry of Agriculture and Forests in Bulgaria regulate the utilization of organic wastes after proper treatment. AD of organic wastes is recommended as a possibility for decontamination of the substrate and mineralization, which eliminates the bad odor substances.

**II. PRECEDING RESEARCH OF OUR TEAM**

Our team has 20-years experience in biotechnological research and AD studies. The most important results of these efforts can be summarized as follows:

1. Due to literature reference studies, reports on international scientific forums and personal contacts we established close scientific **relations with some of the leading European**

**teams**, working on the anaerobic digestion of organic wastes:

2. The **Bulgarian experience** in developing and exploiting biogas plants was studied; the experience of the **German company for regenerative sources of energy TbW** in Frankfurt and the experience of the **Laboratory for Environmental Biotechnology in Narbonne (France)** was studied as well.

3. Long duration experiments were performed in laboratory bioreactors (shown on Fig. 1 and Fig. 2), which helped us to accumulate a lot of **practical experience** [7-11].

4. On the basis of the research in laboratory "pseudohomogeneous" bioreactors with organic wastes from farming (cattle manure mainly), food industry (whey and alcohol production waste) and activated sludge and different mixtures of these wastes in different proportions we formulated the following **main conclusions**:

a) For specific mixtures of organic waste biogas production could increase significantly and at the same time the stability of the process is maintained [12].

b) The use of appropriate stimulating substances (or using wastes, which contain them in the necessary concentrations) and surface-active compounds could also increase biogas production, but it is necessary to do techno-economic calculations in order to take efficient decisions [13,14].

c) Anaerobic digestion of organic wastes in a single "pseudohomogeneous" biogas reactor does not significantly decrease the COD of the effluent compared to the influent, i.e. the degree of depollution is not enough and that's why we study a "cascade" of two bioreactors with different working volumes at the moment (financed by the Bulgarian Science Research Fund) [15].

d) The community of different groups of microorganisms in the biogas reactor is sometimes influenced by some hard-to-measure environmental factors (such as geomagnetic activity and atmosphere pressure) even at stable physicochemical variables (ex. t $^0$C and pH in the biogas reactor), which is one of the reasons leading to unexpected "failures" of the process [16].

5. On the basis of the new knowledge about methane fermentation and data from the laboratory experiments with "pseudohomogeneous" biogas reactors we developed new mathematical models (MM) of the process (using deterministic and artificial neural network approaches) [17-25]. Using them we made the following conclusions:

a) There is an extremal relation of biogas flow-rate (Q) to the dilution rate (D), i.e. for a certain D there is a maximum value of Q ($Q_{max}$). This value of $Q_{max}$, however, is very close to the upper technological bound $D_{up.}$, above which the phenomenon "wash-out" of the microorganisms takes place and the process is not stable any more.

b) $D_{up.}$ is in a non-lineal relation to the concentration of the influent organic matter in the biogas reactor $S_{0i}$, which value is very hard to measure and that is why seeking maximal Q could easily destabilize the process. There could be an improvement if we use a "biofilm" bioreactor.

c) The extremal relationship Q = f(D) (Fig. 3) is closely related to the parameter $S_{0i}$, as for different values of $S_{0i}$ $Q_{max}$ changes not only in value, but it also changes its place in regard to D (i.e. $D_{max}$ also changes). But since in real conditions $S_{0i}$ changes with time (i.e. this is the main disturbance for the process), working close to $Q_{max}$ is possible only if there are a computer control system and appropriate sensors. Then, however, it is necessary to do some techno-economic calculations.

6. On the basis of the accumulated knowledge with experimental and simulation research and MM we developed and studied new highly **efficient algorithms** for the methane fermentation process control [26-32].

7. The **influence of heavy metals** on microorganisms' growth and productivity was studied for obtaining biological (ecological) products and detoxication of waters polluted with petrol derivatives [33-37].

Part of the accumulated knowledge is taught to students of several universities.

The research team consists of scientists and specialists from BAS (Institute of Microbiology) and three universities ("Prof. Assen Zlatarov" University, Technical University of Sofia and New Bulgarian University).

The research team in **Module 1** has long experience in studying the methane fermentation in laboratory bioreactors (including the cascade of two bioreactors shown on Fig. 2) with different organic wastes; its intensification applying stimulating substances, surface active compounds, mathematical modeling, computer simulation and modern optimization methods. Three projects were supported by the Bulgarian National Scientific Research Fund (NSRF) and one project - by the INCO-COPERNICUS European program. Two scientists having academic rank at the Technical University in Sofia have been included in this team in order to extend the research on the practical realization of the main energy product (biogas).

The research team in **Module 2** has accumulated theoretical and practical experience in studying the problems of bioaccumulation of metal ions in microorganisms carrying out different biotechnological processes and experience in using immobilized cells and enzymes in detoxication of many xenobiotics and heavy metals. In this area two projects have been supported by the NSRF and one by the European Union.

The scientific results of the **Module 3** team allow to make an ecological assessment of the content of toxic chemical elements in compost. For 7 of these elements there are normative documents for the MRL (maximum residue level) values in Ordinance №22/2001. The research that was carried out indicates that, in the conditions of the used technology, a 49.27% degree of degradation of organic matter is reached and all low molecular organic compounds, which characterize the odor of organic wastes, are mineralized. All pathogenic microorganisms and eggs of helminthes are exterminated. The consistence of the organic wastes also changes and this makes it possible to disperse it with machines used for dispersion of fertilizers

**III. OBJECTIVES, HYPOTHESES, APPROACHES**

**OBJECTIVES OF THE RESEARCH.**

**The main objective** of our project is the comparative study and the development of more efficient technologies for heat and electric power production from farm and food industry organic wastes (specific and mixtures) in heterogeneous biofilm bioreactors and in "pseudohomogeneous" bioreactors.

This project solves the following tasks:

1. **Accumulating new knowledge** about

a) the mechanism of anaerobic digestion of organic wastes in heterogeneous "biofilm" bioreactors and in "pseudohomogeneous" bioreactors (including pilot biogas plant shown on Fig. 5) through interdisciplinary research in laboratory conditions on the basis of our previous experience [38-47].

b) the influence of various concentrations of heavy metals on growth and productivity of microbial societies, taking part in different stages of the methane fermentation, realized through different technologies; the factors of that influence; the rate of metal ion detoxication, through their assimilation by microbial cells; the residual concentrations of heavy metals in the compost from different substrates.

c) expanding the knowledge about AD not only as a technology for gas fuel production, but as a possibility for compost production - an alternative of fertilizers.

2. **Assessment of the degree of microbial decontamination** of AD by studying the survival of the mesophilic aerobe and the facultative anaerobe bacteria, coliform bacteria, proteous bacteria, pathogenic microorganisms (salmonella, pathogenic staphylococcus bacteria), fungi.

3. Study on the movement of energy and biogenic (and toxic) chemical elements along the chain "fodder-manure-compost" (produced by methane fermentation). For comparison we will analogically research composting in our project developed composting installation. We will determine the energy in the substrates (compost produced by methane fermentation and compost produced by composting) and the quantity of biogenic and toxic chemical elements as well.

4. Ecological assessment of compost as a product for increasing soil fertility according to the criteria: biogenic macro- and microelements; toxic elements' content; energy; degree of mineralization. The assessment will be in two directions: opportunities for application of compost for increasing soil fertility in ecological agriculture and biogenic and toxic elements content in

compost comparing it with the basic physico-chemical indices of fertilizes.

5. Development and application of modern **mathematical methods and models for optimization** of the methane fermentation of organic wastes in heterogeneous "biofilm" bioreactors and in "pseudohomogeneous" bioreactors.

6. **Increasing the energy efficiency** in heat and electric power production from organic wastes by optimizing the organization of the mass and the energy flows in biogas plants on the basis of the new knowledge and mathematical models.

7. Application of the obtained results for designing **economically efficient biogas plants**, popularization of the results and their application in practice on the basis of our previous experience [48-51].

**A BASIC HYPOTHESIS** in our research is that heat and electric power production through methane fermentation of organic wastes from farming and food industry could be economically efficient when estimating the energy efficiency of the products – energy resource (biogas) and a substitute of the high energy consuming fertilizers (compost) – and the ecological effect of the optimized (in Bulgarian conditions) technologies.

**Another hypothesis** is that presence of heavy metals can shift (modulate) the process in various directions. Which one of the ions and what concentration will influence the reactions will depend on stability of individual members of microbial society or at least on the physiology group. As the composition of microbial society depends on the type of the substrate, undergoing anaerobe fermentation, the influence of metal ions would be referred to the substrate. Experiments will be performed in a real AD process. Adaptation of the society is possible, so the process can continue even at different rates. The adaptation is usually connected with ion absorption in the cells. Thus, their concentration in the media will decrease while at the same time it will increase in the solid residue containing microorganisms as well.

**The third hypothesis** is that compost is an alternative of high energy consuming fertilizers and it is good for increasing soil fertility due to its optimal content of biogenic macro and microelements, energy content and lack of pathogenic microorganisms and eggs of helminthes.

**THE APPROACH** of the research is complex and interdisciplinary. Using microbiological and biochemical research and analyses, bioprocess engineering, automatics and computer science methods; experiments in laboratory bioreactors and applying modern mathematical techniques will help the accumulation of new knowledge about the methane fermentation process, stabilization of the process and its optimization.

**IV. METHODS, EQUIPMENT, RESEARCH TECHNIQUES, DATA ANALYSIS**

1. Isolated and screened microbial societies responsible for every stage of the methane fermentation will be used during the project development. For this purpose specific microbiology methods, requiring anaerobe cultivation conditions will be applied. They will be realized either according to the principle of high layer growth media or in special boxes and exicators filled in with inert gas. Heavy metal analysis will be performed by **atom absorption spectral analysis or specific chemical methods.**

2. The quantity of biogenic and toxic elements will be determined applying the method of atomic absorption using an atomic absorption spectrophotometer. The quantity of nitrogen, hydrogen, carbon and oxygen will be determined using a gas chromatographer or **specific flame–detector analysis** and the obtained data will be used for calculating the energy.

3. The most modern methods of bioprocess engineering for organization and performance of laboratory experiments will be applied.

4. Chromatographic methods and techniques for laboratory analyses and biochemical methods for studying the role of some surface-active compounds (biological and chemical) for intensification of the processes will be used.

5. Methods of mathematical and neural modeling and computer simulation will be applied.

6. Methods and algorithms of the modern theory of automatic control (non-linear estimation, extremum-seeking, non-linear and adaptive control) will be used.

**V. RESEARCH PLAN**

1. Upgrading and automation of the laboratory "pseudohomogeneous" biogas reactors for performing all-year-long experiments as well as development and construction of two anaerobic "biofilm" bioreactors with moving and stable supporting beads.

**2. Construction of a laboratory composting installation.**

3. Experiments on anaerobic digestion of organic wastes from farming and food industry (single substrate or different mixtures) in laboratory "pseudohomogeneous" biogas reactors and in anaerobic biofilm bioreactors with monitoring and regulation of the main influent and effluent variables (t $^0$C, pH, rH, concentration of the basic components in the influent and in the effluent as well, biogas production, methane content (%)); experiments with chosen concentrations of heavy metals).

4. Chemical analysis of metabolites typical for the different stages of fermentation and model fermentation solution preparations.

5. Development of methods for granulation and preservation of the activated sludge.

6. Isolation and preservation of microbial society consisting of specific functional groups.

7. Study on the influence of heavy metals effect (Cu, Zn, Cd, Ni, Pb) on the isolated microbial society in model mixtures.

8. Biochemical analyses for studying the process kinetics in bioreactors and analysis of the experimental data.

9. Development of process intensification methods using different stimulating substances and surface active compounds.

10. Development of: a) mathematical and neural models of the methane fermentation; b) new methods and software techniques for obtaining information about the main variables and parameters; c) methods and algorithms for optimization and control using the new knowledge and the stimulating substances as input actions for optimization of the process (increasing biogas production).

11. Ecological assessment of compost from different resources and using different technologies for biogas production according to: a) energy content, biogenic and toxic elements content and regarding the norms in Ordinance №22/2001; b) the degree of microbial decontamination estimated through the inoculation of the substrate with marked pathogenic microorganisms.

12. Research on the energy efficiency of heat and electric power production using methane fermentation of organic wastes in different types of bioreactors.

13. Proposal of an efficient biogas production technology based on organic wastes

**VI. EXPECTED RESEARCH RESULTS**

**Expected scientific and practical application achievements**

1. Extended knowledge of biodegradation efficiency of different substrates related to the operating mode of bioreactor and treatment with surface-active compounds for increasing biogas production.

2. New knowledge of the processes of anaerobic digestion in "pseudohomogeneous" and in "biofilm" bioreactors from their comparison and finding out their optimal working regimes with different organic wastes for their practical application in biofuel production.

3. Isolation and identification of active microbial society during the stages of the methane fermentation process based on different organic substrates.

4. Finding out the modulate effect of different heavy metal concentrations during the fermentation.

5. Determination of the rate of substrate detoxication regarding heavy metals.

6. Objective assessment of advantages and disadvantages of the two basic biotechnologies for organic wastes treatment - methane fermentation and composting.

7. New knowledge is expected about the possibilities for microbial decontamination for the actual parameters of the methane fermentation (temperature, retention time, etc.).

8. Development of new dynamic models, methods and software techniques for obtaining information about the main variables and parameters of AD.

9. Development of methods for the process intensification using different stimulating substances and surface-active compounds.

Fig. 1. Our first laboratory biogas plant

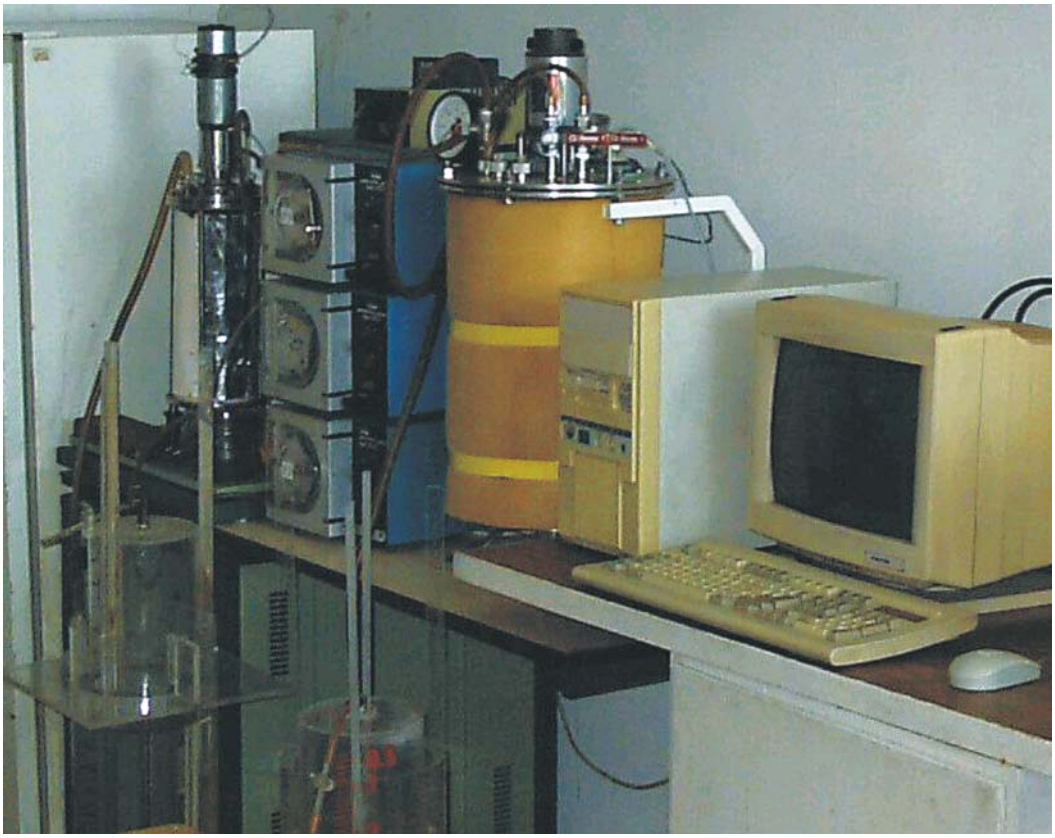


Fig. 2. Laboratory cascade of two anaerobic bioreactors

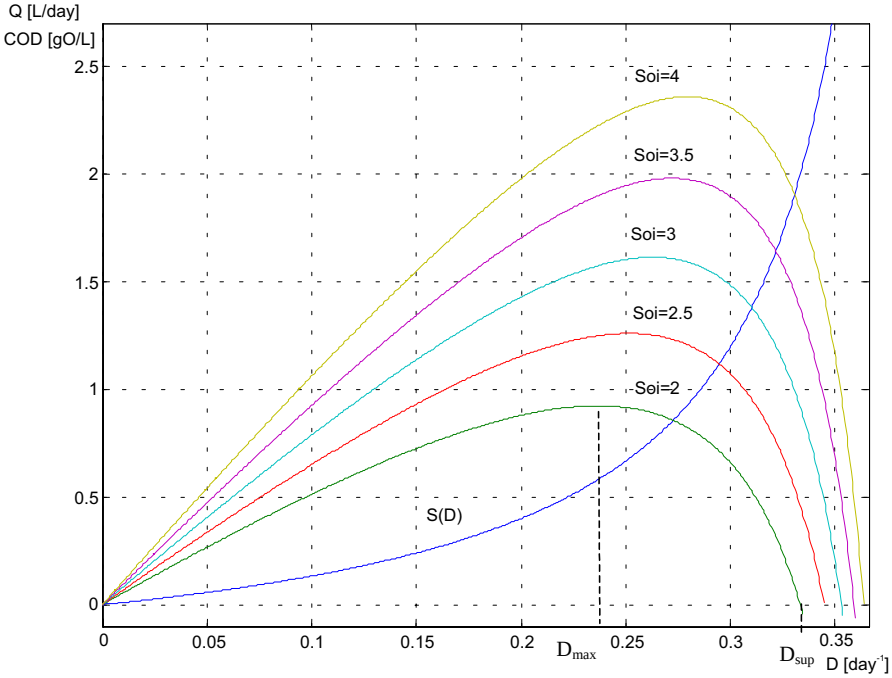



Fig. 3. Static input-output characteristics for 2nd order AD model (Mono case)

Fig. 4. Small laboratory anaerobic bioreactors

Fig. 5. Our pilot biogas plant

10. New possibilities for optimization and control of the methane fermentation in order to increase its energy efficiency.

11. From a practical point of view the achievements of our team will be presented as proposals for new efficient biogas technologies for heat and electric power production from organic wastes.

***Ways of spreading the results***

Our result achievements will be published in Bulgarian and international journals and/or will be presented at different scientific forums (conferences, symposia and congresses). They will be used in lectures and published in one monograph as well.

***Results application in practice and in education***

The research will find application in the education of students, specialists and PhD students.

***Economic interest***

Significant amount of money will be saved for buying the "know-how" from foreign companies for the future development of biogas industry in Bulgaria.

References

1. Price E. C., P. N. Cheremisinoff. Biogas Production and Utilization. Ann Arbor Science Publishers, Michigan, 1981.

2. Viesturs U.E. Biotechnology: Bioagents, Technology, Equipment, Zinatne, Riga, 1987 (in Russian)

3. Forester Ch. F., D. A. John Wase. Environmental Biotechnology. Ellis Horwood Limited, N. Y., 1987.

4. Dubrovskiy V. S. and U.E. Viesturs. Anaerobic Digestion of Agricultural Wastes. Zinatne, Riga, 1988 (in Russian)

5. Tzachev Tz. Waste Waters Treatment, Part 1 – Domestic Waters Treatment. Mertilen, Sofia, 1991 (in Bulgarian).

6. Mirkov A., I. Simeonov**.** Experimental Biogas Plant "Podgumer", Young Scientists School "Biogas Technologies for Energy Regeneration". Sofia, April 22-24, 1998, pp. 17-20 (in Bulgarian).

7. Simeonov I., Results from laboratory investigations and some recommendations for biogas production from manure. **Workshop "Ecological Energy Technologies Using Biomass and Biogas in Bulgaria"**. (Invited paper), Troyan, November 5, 1998, pp. 71-84 (in Bulgarian).

8. Baykov, B., M. Stoyanov, M. Gugova. Methane fermentation of dung from litter-free reared domestic animals - an optimisation study. **Resources, conservation and recycling**, 13, 1995, p. 251-256.

9. Baykov, B., M. Dimitrova, M. Stoyanov. Bioenergetics of an ecotechical system of laying hen farms. **Ecological engineering,** 4, 1995, p. 307 – 319.

10. Baikov, B., N. Petkov, R. Nenov, V. Chichibaba, M.

Ivanova, D. Tyrawska. Assessment of methanogenesis as a possibility of microbial decontamination of the dung and preservation of its biogenic elements.VII Int. Congress on Animal Hygiene, Leipzig,1991, p.597 – 609.

11. Baikov, B., M. Stoyanov, B. Somlev, M. Ivanova, E. Dodova. Ecological studies on the development of new technologies for utilization of manure from layng hens. **XIX World's Poultry Congress**, Amsterdam, 20 – 24 September,1992,vol. 2, p. 292–293.

12. Николов Л., И. Симеонов, Д. Каракашев, Е. Чорукова, Д. Гълъбова. Анаеробна деградация на сложни смеси от органични отпадъци. Екологично инженерство и опазване на околната среда, 3, 2004, 42-52

13. Simeonov I, D. Galabova, I. Queinnec. Investigations and mathematical modeling of the anaerobic digestion of organic wastes with addition of electron acceprtors. 9th **World Congress "Anaerobic Digestion"**, September 2-6, 2001, Antwerpen, Belgium. Proceedings, Part Two, p.301-385.

14. Simeonov I., D. Galabova. Investigations and mathematical modeling of the anaerobic digestion of organic wastes. **5th Int. Conf. on Environmental Pollution, Thessaloniki**, August 28 – Sept. 1, 2000, p.285-295.

15. Симеонов И. Лабораторни изследвания и математическо моделиране на анаеробното разграждане на органични отпадъци в каскада от биореактори. Екологично инженерство и опазване на околната среда, 2, 2005, с.51-57

16. Karakashev D., D. Galabova , I. Simeonov. A simple and rapid test for differentiation of aerobic from anaerobic bacteria. **World J. Microbiol. Biotechnol.,** 2003, 19, p.233-238.

17. Simeonov I, A. Naamane. Hybrid mathematical modeling and pH control of anaerobic waste waters treatment processes. **Int. Conf. AIS,** Lisbonne (Portugal), April 7-10, 2002, p.175-179

18. Simeonov I. Dynamic modelling of the methane fermentation. **Conf. on Application of Models in Water Management**. Amsterdam, Sept. 24-25, 1998, p.133-136.

19. Simeonov I., E. Chorukova, B. Kalchev. Anaerobic digestion modeling with artificial neural networks, **CAB9**, Nancy, France, March 2004 (accepted)

20. Lubenova V., I. Simeonov, I. Queinnec. Two-step parameter and state estimation of the anaerobic digestion, **15th IFAC Word Congress**, Barcelona, July 21-26, 2002.

21. Simeonov I. Mathematical modeling and parameters estimation of anaerobic fermentation process. **Bioprocess Eng.,** 1999, 21, 4, p.377-381.

22. Simeonov I. Mathematical modeling and parameters estimation of anaerobic fermentation process. **European Control Conference** (ECC'99), Karlsruhe (Germany),31. August – 3. Sept.,1999,paper ID273 (on CD).

23. Simeonov I. Modelling and control of biological anaerobic waste waters treatment processes. **Int. Journal "Archives of Control Sciences"**, 1999, 9, 3-4, p.53-78

24. Simeonov I. Modelling and control of anaerobic digestion of organic waste**. Chem. and Biochem. Eng. Q.,** 1994, 8 (2), p.45-52.

25. Simeonov I.,V. Momchev, D. Grancharov. Dynamic modeling of mesophillic anaerobic digestion of organic waste. **Water Research**, 1996, 30, 5, p.1087-1094.

26. Simeonov I., I. Queinnec. Linearizing control of the anaerobic digestion. **Control Engineering Practice**, 2006.

27. Simeonov I., J.-P. Babary, V. Lubenova, D. Dochain. Linearizing control of continuous anaerobic fermentation processes. **Int. Symp. "Bioprocess Systems'97"**, Sofia, Oct.14-16, 1997, III. p.21-24.

28. Simeonov I., S. Stoyanov. Modelling and dynamic compensator control of the anaerobic digestion of organic wastes. **Chem. Biochem. Eng. Q.,** 2003, 17 (4), p.285-292

29. Simeonov I., S. Stoyanov. Dynamic output compensator control of methane fermentation. **Workshop on Monitoring and Control of Anaerobic Digesters**. Narbonne (France), Dec. 6-7, 1995, p.47-51.

30. Stoyanov S**.,** I. Simeonov. Dynamic output compensatory control of continuous anaerobic fermentation process. **IMACS/IFAC Int. Symp. on Math. Modelling and Simulation in Agricultere and Bio–industries**, Brussels, May 9-12, 1995, II.B.5-1 - II.B.5-6.

31. Stoyanov S., I. Simeonov. Robust compensatory control of continuous fermentation processes. **Bioprocess Engineering**, 1996, 15, 6, p. 47-51.

32. Zlateva P., I. Simeonov. Variable structure control of methane fermentation. **System Modelling Control**, 1995, 8, 2, p.433-436.

33. Kaimakchiev A., D. Denchev, M. Gerginova, Z. Alexieva. The effect of Cu 2+ and Cd 2+ on citric acid production by *Saccharomocopsis lipolytica* strains. J. Biotech. Biotechnol. Equip., 1998, 1, p.56-63.

34. Tsekova K., D. Denchev, D. Todorova. Effect of Cadmium and Cupper on the production of citric acid by *Aspergillus niger*. Folia Microbiol., 2000, 45, 4, p.321-327.

35. Godjevargova Ts*.,* D. Denchev. Effect of concentration of cuprous (II) ions on cells of *Saccharomocopsis lipolytica* Immobilized into polymer carriers. J. Biotech. Biotechnol. Equip., 2002, 16, 2, p.150-156.

36. Godjevargova Ts*.,* S. Mihova, D. Denchev. An investigation of kinetics of Cu(II) biosorbtion on the immobilized cells of *Saccharomocopsis lipolytica-2.* J. Biotech. Biotechnol. Equip., 2002, 16, 2, p.157-163.

37. Tsekova K., D. Denchev. Cupper (II) stress response in submerged cultures of *Aspergillus niger.* IM-13, Comp. Ren. Acad. Bulg. Sci, 2003, 56, 3, p.49-52

38. Karamanev D., L. Nikolov. Application of Inverse Fluidization in Wastewater Treatment: From Laboratory to Full-Scale Bioreactors. **Environmental Progress**, 1996, v.15, p.194-197.

39. Karamanev D., L. Nikolov. Influence of Some Physicochemical Parameters on Bacterial Activity of Biofilm: Ferrous Iron Oxidation by *Thiobacillus ferooxidanse.* **Biotech. and Bioeng**., 1988, v.31, p.295-299.

40. Mamatarkova V. S., L. Nikolov, D. Karamanev. Biofilms: Problems and trends in Research Activity: Part I. Structure and Processes in Biofilms and Their Surroundings. **Biotechn. and Biot. Equipmt.**, 2002, 2, p.170-177.

41. Mamatarkova V. S., L. Nikolov, D. Karamanev.

Biofilms: Problems and trends in Research Activity: Part II. Structure and Processes in Biofilms and Their Surroundings. **Biotechn. and Biot. Equipmt**., 2002, 2, p.200-208.

42. Nikolov, L., D. Karamanev. "Bioreactor", **Bulg. Invent**. No.48849, MPKC 03 02 F 3/08/24.02.1989.

43. Nikolov,L. "The Bioreactors - Basic Equipment for Biotechnology Processes". **Biotechnology and Chemistry**, (Bulg.), (1989) No.6, pp.46-47.

44. Mamatarkova, V., L. Nikolov, D. Karamanev. (2002) "Biofilms: Problems and Main Trends in Research Activity", Part I. **Biotechnology and Biotechn. Equipmt.** No1, pp.170-176.

45. Mamatarkova, V., L. Nikolov, D. Karamanev. (2002) "Biofilms: Problems and Main Trends in Research Activity", Part II. **Biotechnology and Biotechn. Equipmt.** No1, pp. 200-208.

46. Nikolov, L., D. Karamanev, D. Elenkov. "Bioreactor with a Moving Bed", **Bulg. Invent**. No.32910/09.10.1981.

47. Lazarova, V., B. Capdeville, L. Nikolov. (1994) "Influence of Seeding Conditions on Nitrite Accumulation in a Denitrifying Fluidized Bed Biofilm Reactor". **Water Research**, v.28, No 5, pp.1189-1197.

48. Krusteva A., V.Lazarov, Z. Zarkov, Hr. Hristov. Renewable Energy Sources and Distributed Energy Production – European Trends. **2nd International Conference on ECOLOGICAL PROTECTION OF THE PLANET EARTH,** 5-8 June 2003, Sofia. Proceedings, pp.512-516

49. Krusteva A., I. Ivanov. Bioenergy - European view, Bulgarian studies and research interaction. **2nd International Conference on ECOLOGICAL PROTECTION OF THE PLANET EARTH,** 5-8 June 2003, Sofia. Proceedings, pp.516-523

50. Ivanov I., A. Krusteva. Integration in BIO-energy Research and Applications in Bulgaria. **EC Conference 6 FP–BIO–ENERGY ENLARGED PERSPECTIVES,** 16-17 October 2003, Budapest, Poster N 35

51. Krusteva A., V. Lazarov, Hr. Hristov, St. Nedelcheva. Bulgarian Energy Sector and the Experience in the Field of Renewable Energy Sources and Distributed Generation. **2nd annual meeting of the EC project ENIRDGnet.,** Vienna, 19-20 February 2004.

# SOLAR CELLS TECHNOLOGY BASED ON III–V HETEROSTRUCTURES

**Assoc. Prof. Petko Vitanov, PhD; Assoc. Prof. Ekaterina Goranova, PhD** -
Central Laboratory of Solar Cells and New Energy Sources, Bulgarian Academy of Sciences,
72, Tzarigradsko Shose Blvd., 1784 Sofia, E-mail: vitanov@phys.bas.bg
**Dr. Malina Milanova, PhD;** Central Laboratory of Applied Physics,
Bulgarian Academy of Sciences, 59, St. Petersburg Blvd., 4000 Plovdiv

## 1. Introduction

Photovoltaic conversion of highly concentrated solar radiation is one of the most promising ecologically clean methods for electric power generation. The new generation of solar cells (SC) on GaAs uses the total solar spectrum and operates at high levels of solar radiation concentration. The cells consist of multilayer heterostructures of two and three component solid compounds on the basis of GaAs and the elements Al, P, Sb, In.

The low temperature liquid epitaxy from melted solution allows the growth of thin multilayer heterostructures, the quality and production costs of which make a good combination. Another point is that the technological equipment is much cheaper than the gas phase deposition one.

The development of a technology for deposition of $A^3B^5$ heterostructures on GaAs and Si substrates for high efficiency solar cell fabrication is the goal of a project funded by the National Scientific Programs.

Groups from three partnering institutions take part in the present project: The Central Laboratory of Applied Physics (CLAP) – Plovdiv, the Semiconductor Physics Chair (SPC) at the Physics Department (PD) of Sofia University (SU) "St. Kliment Ohridski" and the Central Laboratory of Solar Energy and New Energy Sources (CL SENES) at the Bulgarian Academy of Sciences, Sofia.

## 2. Main Objectives of the Project

2.1. Developing a technology for fabrication of multilayer AlGaAs/GaAs and InGaAsSb/GaSb heterostrucures for production of high efficiency photocells with a single p-n junction, as well as two cascade solar cells.

2.2. Developing a technology for fabrication of AlGaAs/GaAs heterostructures on Si

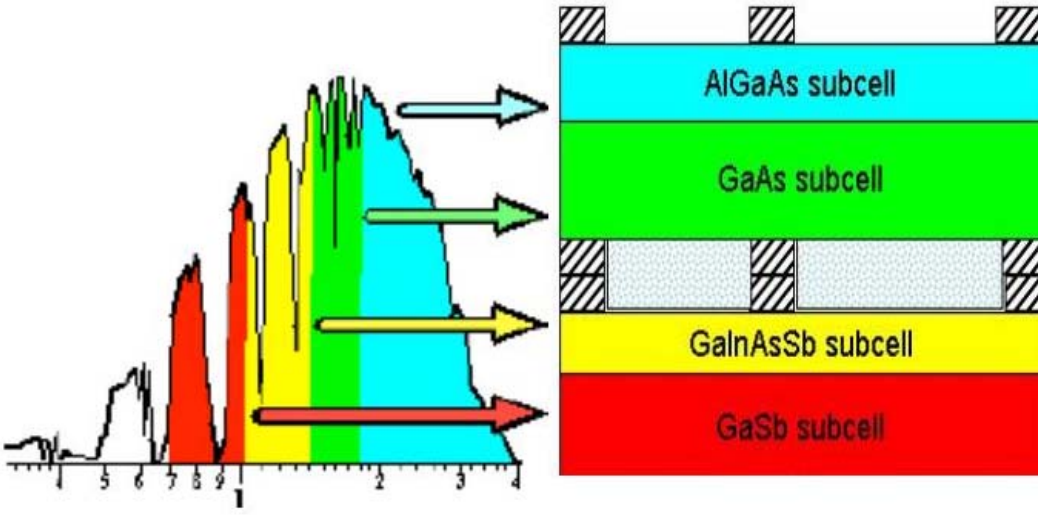



Fig.1. The schematic structure of the proposed tandem cell

substrates with characteristics close to those obtained on GaAs substrates.

In order to reduce photocell production costs, a suggestion is put forward cheap silicon substrates to be used instead of the expensive GaAs ones. Thin epitaxial $A^3B^5$ layers will be grown on the silicon substrates in order to form an effective heterostructure.

Structural, electrophysical and optical characteristics of one-layer control systems and heterojunctions to them will be studied. Dependence of these characteristics on the technological epitaxial regimes will be sought for their optimization. These studies will be conducted on an early stage of solar cell formation in order to achieve more effective technology and cost decrease. The envisaged characterization methods include microscopic characterization of heterostructure surfaces and interfaces by optical and scanning electron microscopy in the topography and composition contrast regimes, electrophysical measurements and optical characterization of control layers and cross sections of multilayer heterostructures. An independent estimation of composition and doping is planned, too.

Computer simulation will be used for photocells design. That will include an estimation of surface area, structure technology and metal contacts mask elaboration. Electrical measurements on a solar simulator, as well as physical analysis of device characteristics will enable the respective device corrections to be performed. The aim is to realize small area photocells, appropriate to function in modules with concentrators. The main hypothesis is connected with the assessment of possibilities heterostructures to be realized by means of liquid phase epitaxy, suitable for high efficiency solar cells. A complex approach will be used to prove this hypothesis and it is connected with modeling, design and evaluation of structures like solar cells.

**3. Liquid Phase Epitaxy Growth of AlGaAs/GaAs Heterostructures**

The low-temperature Liquid Phase Epitaxy (LPE) method is usually used for III-V cell heterostructures fabrication. LPE is a simple inexpensive and nontoxic method for high quality AlGaAs/GaAs heterostructure fabrication. The reduction of growth temperature down to 600-400°C ensures precise crystallization of the ultra thin (2-20 nm) planar layers. $Al_xGa_{1-x}As$ layers (x=0.3-0.5) can be obtained by LPE. High-quality multilayer $Al_{0.35}Ga_{0.65}As$/GaAs heterostructures for single-junction solar cells will be fabricated by the low-temperature LPE.

Monolithic growth of the entire structure is easy because $Al_xGa_{1-x}As$ for all the values of x is almost completely lattice matched to GaAs. High efficiency of over 30% is expected though the AlGaAs/GaAs material is not the optimum with respect to bandgap energy in a tandem solar cell. The interconnection between the

AlGaAs top and the GaAs bottom cell consists of GaAs tunnel junction sandwiched between AlGaAs layers. The thickness of the heavily doped $n^{++}$ and $p^{++}$- GaAs tunnel junction region is as thin as possible (5-10 nm) in order to minimize absorption losses of sunlight absorbed in GaAs cell. Progress in low-temperature LPE allows us to achieve complicated multilayer AlGaAs/GaAs heterostructures for monolithic two-junction two-terminal tandem cells of efficiency higher than 30% under concentrated light. The schematic structure of the proposed tandem cell is plotted in Fig. 1.

In cooperation with the "A. F. Ioffe" Physical Institute in Sankt Peterburg a method has been developed at CLAP for low temperature LPE and AlGaAs/GaAs heterostructures of quantum size layers have been prepared [1]. High efficiency GaAs SC for non-concentrated solar radiation are also developed and prepared. The SCs have maximum photosensitivity in the spectral range between 500 and 900 nm and elevated photosensitivity in the UV region. The highest solar cell efficiency obtained for 1 $cm^2$ area under non-concentrated solar radiation is 23.4% and it is comparable to the highest values for solar cells operating under non-concentrated light [2].

**4. Expected Results**

A technology will be developed for fabrication of $A^3B^5$ heterostructures deposited on GaAs and Si substrates for high efficiency solar cells.

Experimental structures suitable for photoelectric conversion will be prepared.

Possibility for realizing solar cells on the basis of $A^3B^5$ heterostructures on Si substrates will be assessed.

**Acknowledgements**

This work was supported by National Scientific Programs "New energy technologies"

References

[1] M. Milanova and V. Khvostikov, J. Cryst. Growth, 219 (2000) 193

[2] M. Milanova, A. Mintairov, V. Rumyantsev and K. Smekalin, JEM, 28 (1999) 35

# BULGARIAN ADDED VALUE TO ERA

## BULGARIAN CENTER OF SOLAR ENERGY – CENTER OF EXCELLENCE IN SOLAR TECHNOLOGIES

**Assoc. Prof. Petko Vitanov, PhD**
Director of Central Laboratory for Solar Energy and New Energy Sources, BAS

Central Laboratory for Solar Energy and New Energy Sources (CL SENES) at the Bulgarian Academy of Sciences has been carrying out research activity in solar energy in Bulgaria since the late 70s. A considerable scientific potential in the field is concentrated in it. During the 80s the principal tasks of the Laboratory mainly related to fundamental investigations on material featuring and technology development for solar energy utilization.

Two are the basic directions of specific activities:

- Photovoltaic solar energy conversion, including preparation and study of new materials and technologies for solar cells, investigations of modules and solar system design;

- Photothermal solar energy conversion including development of selective coatings, energy controlled coatings, solar collectors and heat accumulation.

The structural changes in energy, industry and society taking place in the last few years put ahead new requirements for the research activities in renewable energy sources and those demanded new organization of research and applied work of the CL SENES. Contacts were established with the leading groups in Europe for joint participation in projects supported by the European Commission (EC). The Laboratory backed up the RES involved non-governmental organizations by expertise and consulting. The contacts with the energy institutions become closer and now the Laboratory is one of the principal consultants in "clean energy" problems for the state administration.

In February 2003 CL SENES was selected as a Center of Excellence in the frames of the 5$^{th}$ WFP EC Program project responsible for coordination of scientific research and training in the field of solar energy application at national level.

This new disposition required broadening of the fields of activity of the Laboratory and it was approved as the Bulgarian Center of Solar Energy (BGCSE).

**Through research, implementation, consulting and education activities the Center aims at three principal goals:**

1. Rise of the scientific and technological level of "clean energy" production.

2. Promoting the rapid implementation of solar systems and installations.

3. Improvement of education on, and understanding of the potential and wide implications of solar energy use, its significance for human welfare and the environment, within the framework of sustainable development.

**To achieve them the Center is considering the following problems:**

1. Development of advanced technologies of solar energy elements and systems adaptable for industrial production.

2. Scientific support for organization and transfer of new productions for solar energy installations.

3. Education and training in the field of solar energy.

4. Support and development of socially

engaged significant demonstration projects.

5. Formation of a working group for solar system test methods and standard preparation and establishment of an authorized certification unit.

6. Building an international testing ground for solar energy devices and systems.

7. Improving links with non-governmental organizations by consulting, joint workshop and event organization, project commitments, etc.

Realization of the above mentioned problems will contribute to industry restructuring through new production implementations and creating new working places. Application of the solar energy technology will raise the ecological culture and human life quality and will reduce the harmful emissions from the conventional energy production.

The particular activity of the Center coincides with the science development priorities in Bulgaria and closely relates to the principal priorities of the $5^{th}$ and $6^{th}$ Frame EC program.

The significant innovative elements in the Center activity concern the following items:

- Creation of conditions for developing advanced technologies applicable in industrial production.

- Realization of demonstration projects of substantial social and energy impact.

- Solar energy installation testing and certification.

- Preparing the organization of an international solar energy regional center.

Based on the obtained research results, development and transfer of advanced technologies suitable for solar energy conversion devices and installations are envisaged. Three of the trends are assessed as the most adequate:

Research in the field of technologies for solar cells:

- *Low cost technology for highly efficient crystalline Si solar cells*. The availability of original results and patents permits solar cells of 17-19% efficiency to be produced without expensive or sophisticated processes. In the frames of the ADVOCATE project (NNES5-2001-0703) researchers from the CL SENES participated actively in developing an advanced technology for high efficiency solar cells on thin multicrystalline silicon wafers. Partners in these projects were 4 companies – IMEC (Belgium), Photowatt (France), Second Semiconductor Equipment (Austria), FAP (Germany), 2 universities and 2 institutes. Part of the obtained results is published in 11 publications and 1 patent (EP 1 489 667 A).

"High Efficiency Silicon Solar Cells with Low-Cost technologies" workshop was held in Sofia in May 2004. The basic topics concerned low-cost technologies suitable for industrial upgrading and that was the reason to look for among researchers involved in that particular area. 5 scientists from leading companies and institutes took part as invited lecturers. Scientists from CL SENES and the Faculty of Physics at Sofia University delivered lectures, too. Overall, 58 specialists from institutes of the Bulgarian Academy of Sciences, Sofia University, South-West University in Blagoevgrad, Technical Universities in Sofia and Varna, engineers from companies in the electronic industry participated in the event. 19 of them were young people below 35.

- *Thin film solar cell technologies*. Previous investigations on amorphous Si, CdTe, CdS and $CuInSe_2$ (CIS) thin films provided the base for working groups from the Laboratory to be included in the EC supported JOULE Program. The achieved results stimulate further efforts an end product to be created. At the end of September 2005 a "Low Cost Technologies for Thin Film Solar Cells" workshop was held in Sofia on the problems. The main topics were: CIS based solar cells, thin film silicon solar cells, organic and polymer photovoltaic, photo electrochemical and dye-sensitized solar cells. The aim is researchers from Bulgaria and abroad to be informed about the achievements in the low-cost deposition methods for preparation of thin film solar cells and, also, to help in establishing closer contacts among the scientists in the field. Five lecturers from leading European research centers were invited and delivered lectures on the above-mentioned themes. Simultaneously, short announcements were given to present recently achieved results. Discussions and debates on the possibility of joint investigations and participations in future projects took place.

Through workshops, seminars and ex-

change of visiting researchers closer contacts will be established between scientific institutions and producers. Joint development of advanced technologies for industrial production must be a direct result of the Center actions.

The formation of a working group on Standardization of solar thermal collectors and photovoltaic (PV) modules is a new item in the Center activities. Measurements are carried out in accordance with the EU standards under outdoor conditions.

A testing laboratory for PV modules has been created in the CL SENES. It comprises a sun tracking supporting construction (Fig. 1) and a measuring system for electrical characterization of PV modules (Fig. 2). The main purpose is to perform precise operational testing and energy rating of terrestrial photovoltaic modules. Since producers use different technologies for solar cell material (crystalline-Si, amorphous-Si, C-I-S thin film etc.) and different solar cell designs, the installation for testing should be as flexible as possible.

The system for testing water solar collectors has also been developed in accordance with the following EU standards: EN 12975, EN 12976 and EN 12077. Test measurements are carried out in stationary regime and under real conditions. The aim is a laboratory for solar thermal installation assessment and quality certification issues to be organized. It will twin the Laboratory of Testing and development of Solar and Other Energy Systems at the Demokritos Center in Athens, Greece. Our specialists visited the Center and Greek specialists are invited to Sofia to discuss problems connected with testing and assessment of solar installations. A bilateral cooperation is the appropriate way to do this.

Traditionally, each three years CL SENES is organizing a national conference on RES. The Third National Conference on RES was held in October 2003 at the National Palace of Culture, Sofia, under the Honorable Chairmanship of Milko Kovachev, the then Minister of Power Engineering. It was organized as a part of the BGCSE program. 144 specialists took part in the Conference. 46 reports were delivered in the field of solar, wind and geothermal energy and biomass. Institutions of higher education were widely presented and especially technical universities alongside with the institutes of the Bulgarian Academy of Sciences. Representatives of many firms and companies as well as of governmental institutions, NGOs and the media participated, too. The biggest part of reports (25) concerned solar energy utilization, including measuring methods and solar radiation simulation, solar data from different regions in Bulgaria, photovoltaic conversion, passive and active solar thermal systems. A concomitant exhibition on solar thermal technologies in Bulgaria was organized with the kind cooperation of Energy Center Sofia and the Greek center Exergia. 3 Bulgarian and 14 Greek companies took part in it.

The third task of BGCSE relates to further stimulation of solar technology application by training specialists and popularizing the achievements and advantages of solar energy utilization. Those include visits of young researchers to the leading European centers in the field, working on joint projects, organizing and holding common conferences and schools on renewable energy sources for young people.

The National School "Renewable Energy Sources: Nature, Development, Perspectives" was a separate work-package in the Center of Excellence Program. The included topics were selected specially for teaching young specialists, doctorial and post-doc students in various profiles. There were over 25 received lectures covering all the aspects of solar energy utilization: photovoltaics, wind energy, biomass, geothermal, etc. 55 PhD students from 5 academic institutes, 10 universities, 2 companies involved in solar energy took part and there was one application from the European University in Budapest, Hungary, too.

To inspire the interest of the young participants and to stimulate them the PhD students were given certificates for attending a specialized course covering a wide range of the RES utilization fields. That should be considered as separate credit points in favour of their PhD programs. Besides the Program an opportunity was provided video records illustrating some RES technologies and accomplishments in Japan, Poland, Germany, the UK, etc. to be presented.

The possibility of BGCSE to disseminate information about the advantages of solar energy

Fig. 1. A view of the PV module supporting and tracking system

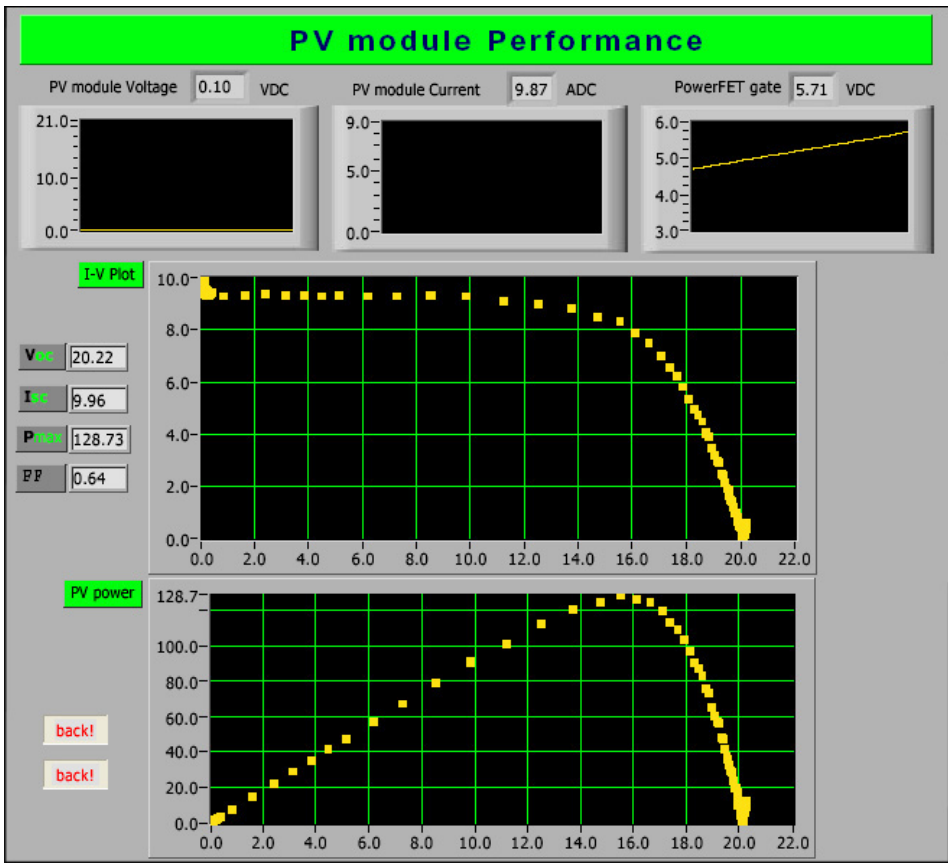


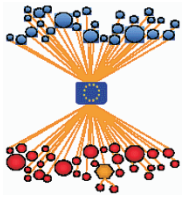

Fig. 2. PC control station

Fig. 3. 10 kW grid-connected PV system

usage grew substantially after a 10 kW grid-connected PV system was put in operation (Fig. 3). This system is built in the frames of an EC project (PN Enlargement) and it is the first demonstrational project of this kind in the country. This system is going to take part in 4-year monitoring together with 26 similar installations in Europe and it has to prove the availability of real resources for decentralized electric energy production. Using local grid-connected solar photovoltaic generators is a promising technology and quite appropriate for the climatic conditions in Bulgaria.

The results of the BGCSE work activated more strongly than expected the RTD activities in solar energy usage. The BGCSE project exhibited the Central Laboratory for Solar Energy and New Energy Sources as the leading scientific unit to which a number of companies and institutions refer to for scientific and technical support. Professional contacts have been established with the "Energy Solution" company which is the only one producing PV modules in Bulgaria now. Our scientific links with leading European science centers in photovoltaic technologies grew stronger. Our scientists and specialists collaborate beneficially with the colleagues from IMEC – Belgium and Photowatt – France. A delegation from India visited the Laboratory after an invitation from the Ministry of Foreign Affairs. We discussed a joint project for building a 1 MW$_p$ Solar Photovoltaic Plant and other joint ventures. Specialists from CL SENES were invited as co-organizers of the Symposia "Environmental Friendly Energy Production in PHARE Countries – Solar Energy" held in Prague and Athens. General Electric Global Research offered their PV modules to be tested by our Test Laboratory under outdoor conditions in the frames of a bilateral contract. Companies from Bulgaria and Europe that produce solar thermal collectors offered their products for testing and that is a good opportunity for close contacts to be established with industry and thus to create the foundation for joint development activities.

Together with other projects in the frames of the EC scientific programs the Bulgarian Center of Solar Energy contributes to the real integration of Bulgaria in the RES policy of the European Union.



# MADE IN BULGARIA WITH EUROPEAN SUPPORT

## New Technological Systems, Using Concentrated and Super Concentrated Solar Energy and Their Utilisation for Power Supply

**Person for contact: Mr. Angel Milev**
Applied Research and Communications Fund (ARC Fund)
Phone: +359 2 9867887, Fax: +359 2 9801833,
Email: angel.milev@online.bg

***Application Area:*** *Alternative Energy; Solar energy*

The most prospective opportunity to eliminate the energy problem is the direct utilisation of solar energy. The scientific and application fundamentals have been developed very well by a Bulgarian inventor.

The essence and operation principle of the invented super concentrated focline and refraction optical solar energy systems is in the concept for two-component super concentration of solar electrical & magnetic radiation. The natural solar radiation enters the stratosphere with a constant density of about 1370 v 2100 W/ml with a dominant spectre content in the optical range with a wavelength between 370 and about 820 nanometres. The solar radiation captured by the Fresnel optical facilities of the high-level components of the system, the toroidal aerostatic concentrators, is concentrated primarily. This process is carried out by the high-level blocks of the solar two-component system at the lower ground levels of the atmosphere. They redirect the radiation as a super-concentrated and energy light flow modified by interference with a spectre (through the lower atmosphere) to the blocks with the ground-based focline and refraction optical solar energy concentrators, which are connected by means of power light ducts to several energy receivers and energy transformers.

The two-component system consists of solar optical concentration blocks and modules, placed high in the atmosphere, and terrestrial solar energy concentration blocks. The purposes of the system are:

1. Production of heat with high potential at a low price. The super concentration of solar energy gives rise to high temperatures of the heating medium in the energy receivers. The temperatures vary between 600°C and 5700°C. The energy flows have 1000 times higher energy concentration than the usual solar radiation on the Earth's surface. The high-potential heating energy is transformed easily in energy for industrial and other purposes.

2. Obtaining of very cheap electrical energy.

3. Obtaining of very cheap drinking and irrigation water directly from air humidity.

**Main Advantages:**

- The system provides electrical energy, heat and drinking water at a very low price.

- Low costs for building and producing the system compared to the ordinary heat (thermal) power plants.

# Method and Equipment for Biogas Production by Anaerobic Digestion of Organic Waste

**Prof. Venko Beschkov, DSc**
Institute of Chemical Engineering
1113 Sofia, Acad. Georgi Bonchev Str., Bl. 103

***Application area:*** *Environment protection, energetics*

The method is based on the well known biochemical processes, running in nature at anaerobic conditions and appropriate temperature. The result is biogas formation containing methane (more than 60% vol.) and carbon dioxide (up to 40% vol.) and energy value more than 26 MJ/nm3.

The developed process and the constructed equipment operate as a plug-flow bioreactor and demonstrate high productivity. The latter is up to 2.5 nm3 biogas/m3 bioreactor/day. Besides, very high utilization of the organic substrate is attained - more than 95%. The process is a mesophillic one, i.e. it is carried out at temperatures between 25°C and 40°C.

The equipment is able to treat wastewater with a very high COD (chemical oxygen demand) loading – more than 50 kg/m3. Its performance is exclusively stable with respect to the substrate nature and origin, to the oscillations in acidity, temperature, prolonged microbial culture starvation, etc. The method is applicable in various organic substrates, discharged from food industry, breweries, alcohol production and agriculture. Two useful issues are combined: wastewater treatment and energy recovery.

An application for patent is submitted to the Bulgarian Patent Office.

The process and the equipment are the result of a project, financed by a contract with the company Unitech Ltd, Dulgopol (Varna district, Bulgaria). An investor for the large-scale practical application is sought at the moment.

# EQUAL IN EUROPEAN RESEARCH AREA

## BULGARIAN VIPs:

**Professor**
**NIKOLAI KOLEV, DSc**

***150 original papers, 50 patented inventions implemented in more than 700 installations mainly abroad for 19 different technological processes***

Prof. Kolev was born in 1933 in Sofia. In 1957 he graduated from the University of Chemical Technology and Metallurgy (UCTM)– Sofia. From 1957 to 1959 he was a Foreman of Shift and Senior Engineer at the Plant for Production of Mineral Fertilizers- Dimitrovgrad. From 1959 to 1962 - Assistant Professor at the Department "Processes and Apparatuses"- (UCTM) Sofia. From 1962 to 1971- Research Associate at the Laboratory of Mass Transfer Processes at the Institute of General and Inorganic Chemistry - Bulgarian Academy of Sciences (BAS). (This Laboratory grew into Central Laboratory in Theoretical Fundamentals of Chemical Technology and afterwards into Institute of Chemical Engineering at BAS). From 1971 to 1983- Associate Professor at the Central Laboratory in Theoretical Fundamentals of Chemical Technology. From 1983 to present - professor and Head of the Laboratory of Heat and Mass Transfer Processes in Gas-Liquid Systems at the Institute of Chemical Engineering - BAS.

In 1967 N. Kolev defended his PhD thesis at the Institute of General and Inorganic Chemistry (BAS). Its title is: "Influence of surface-active agents (frothers) on the hydrodynamics and mass transfer in packed columns." thesis He defended his D.Sc. (Chem. Eng.) in 1981 at the Institute of Chemical Engineering. The title is: "Design of highly effective absorption packed columns, some principal problems of Chemical Engineering." In 1962 he specialized two months at the Institute of Chemical Process Fundamentals at the Czechoslovakian Academy of Sciences in cooperation with Prof. Kolar. From 1967 to1969 he specialized 17 months at the Technical University, West Berlin, Institute of Chemical Engineering (Verfahrenstechnik) under the guidance of Prof. Brauer (a research fellowship awarded by the Alexander von Humboldt Foundation). Additional 10 months – four stays from 1996 to 2003 - he worked at different Universities in Germany (funded by the Alexander von Humboldt Foundation).

Prof. Kolev read the course "Heat and Mass Transfer Processes" at the Chemical Faculty of Sofia University (1982-1987), a lot of courses for qualification of chemists and chemical engineers in Bulgaria and many lectures in different universities in Germany and the USA. He was a research advisor of 5 Ph.D. theses and more than 20 diploma papers.

He has 150 papers, 123 reports and posters at scientific congresses and conferences and 50 patented inventions. His first book "Intensification of absorption and extraction processes" is published in 1968 in co-authorship with the Corr. Mem. of BAS, professors Dimitar Elenkov and Lubomir Boyadzhiev. His second book about packed bed columns is written according to a contract with the publishing company Elsevier and is just submitted for publication.

His investigations are mainly in the field of development of new packings and liquid dis-

tributors. The scale-up problems and the problems of the universal modeling of absorption, desorption, direct heat transfer and rectification in packed columns are solved. The latter became possible after taking into account the axial mixing and the Marangoni effect in the system of non-linear balance differential equations, describing the process to calculate the height of the packing of the column without any laboratory or pilot plant investigations. The new devices and calculation methods are used for construction of 19 different types of apparatuses and installations for absorption, desorption, direct heat transfer and rectification, introduced into industry. The whole number of apparatuses produced after his patented inventions is more than 700, operating in Bulgaria as well as in other countries. Most of the installations introduced into industry are designed for purification of waste waters and gases and for utilization of waste heat of flue gases.

Another area of his activity recently is the elimination or at least strong reduction of the influence of the diffusion resistance on the process rate in catalysts on an activated carbon carrier, and also pyrolysis and burning of waste products, including very dangerous ones.

The external activities of Prof. Kolev are:

- Vice-President of the Union of Chemists in Bulgaria (1991-1992) and since1999.

- President of the Union of Chemists in Bulgaria (1992-1999).

- Member of many scientific consuls.

His international activities are:

- Vice-President of Balkan Environmental Association (BENA) from 1999 to 2003

- Member of the European Federation of Chemical Engineering Working Party on Distillation, Absorption and Extraction.

He is a reviewer of two national and many international journals.

Prof. Kolev has the awards of the Bulgarian and Czechoslovakian Academies of Sciences for the best joint investigations, a Badge of Honor of the inventor in Bulgaria, the award of the Engineer of the Year in the field of Chemical Industry, a lot of awards for contributions in technological advancement, etc.

## Assoc. Professor
## IVAN SIMEONOV, PhD

***Mathematical modeling, optimization and control of microbiological processes and systems***

Born on January 28, 1948 in Dermanzy, Lovech Region. Graduates the Technical University of Sofia in 1971 with a MSc diploma. In 1981 defends Ph.D. in Automatic Control, Technical University of Sofia. Becomes an Assistant Professor at the Central Laboratory of Bioautomation, BAS in1982 and Associate Professor in CLBA in 1986. During the period 1990-94 is Head of the Department Environmental engineering in CLBA. Since 1994 Ivan Simeonov is Head of the Research Group: Mathematical Modeling and Computer Sciences, Institute of Microbiology, BAS.

His Teaching experience includes work at the Faculty of Biology, Sofia University- 1986-88; at the Faculty of Automatics, Technical University of Sofia- 1988-99; and at the Technical University of Gabrovo 2000-01.

**The Main Research Topics of Mr. Simeonov are:**

• Methods and algorithms for mathematical modeling, optimization and control of microbiological processes and systems. The main interest is related with the anaerobic digestion of organic waste in continuously stirred thank reactors (CSTR). Different approaches for stabilization and intensification of this very interesting (from ecological and energetical points of view) anaerobic microbiological process are developed and investigated. It is stressed on the mathematical approach for its modeling and optimization. Mathematical models for optimization of batch and fed-batch fermentation processes

for the enzyme "superoxide dismutase"(SOD) production are also of current interest.

• Videomicroscopy, image analysis and computer taxonomic scientific investigations. The scientific research is carried out in the following fields:

- computer videomicroscopy;
- videodensitometric genome analysis of microorganisms.

**The Most Important Achievements of Ivan Simeonov include:**

» Deterministic nonlinear mathematical models of the anaerobic digestion of organic waste in CSTR are developed and investigated. Mathematical models for optimization of batch and fed-batch fermentation processes for SOD production are in process of validation. New methodology for parameters estimation of nonlinear dynamic models via optimization methods is developed.

» Sophisticated algorithms for control and optimization of the anaerobic digestion of organic waste in CSTR are developed and performed.

» A computer method for videomicroscopic analysis of yeast cells and colonies is created. The computer videomicroscopic approach for obtaining of qualitative and quantitative data from different microobjects is developed for application in microbiological and ecological researches.

» A computer system for videodensitometric analysis of microobjects is created accomplishing quantitative method for classification of microorganisms based on the analysis of their genome. A database is created for accumulation and saving of the information from the electrophoretic images.

» Two PhD students and eleven graduating students from the Technical University of Sofia have prepared and graduated successfully their diploma theses in the scientific area of the group for the last five years.

**Ivan Simeonov participates in a number of Projects, including:**

**National**

• Investigation, modeling and control of the methane fermentation of organic waste. Assoc.Prof. I.Simeonov Grant V RP- TH-7/1999 from the NCSR, Republic of Bulgaria.

• Modeling, monitoring and control of the methane fermentation of organic waste. Assoc.Prof. I.Simeonov Grant TH-657/1996 from the NCSR, Republic of Bulgaria.

• Modeling and optimization of the methane fermentation of complex mixtures of organic waste. Assoc.Prof. I.Simeonov Grant TH 1004/00 from the NCSR, Republic of Bulgaria.

• A computer system for videodensitometric investigations of DNA structures of microorganisms. Research Scientist E.Chorukova Grant MU-I 09/98 from the NCSR, Republic of Bulgaria.

**International**

• Modeling and control of biochemical processes for methane production from organic waste. Assoc.Prof. I.Simeonov BAS - CNRS (France), 1999- 2002.

• Modeling, optimization and simulation of biotechnological processes. Assoc.Prof. I.Simeonov, BAS- University of Marseilles, 2000-2005.

• Biogas-technologies for regenerative energy supply in Eastern Europe "Regenerate". Assoc.Prof. D.Galabova INCO-COPERNICUS project ICOP-DEMO 2023/96.

• Isolation, structural characterization and medical application of SOD from a fungal strain. Assoc.Prof. M.Angelova NATO project No 973 968 (1999-2000).

• Biotechnological production of Cu/Zn-Superoxide dismutase from filamentous fungi. Assoc.Prof. M.Angelova Grant No 436 Bul 113/ 112/0, DFG (Germany).

**Scientific Collaborations:**

**National**

= Department of Biomathematics, Institute for Mathematics and Informatics, BAS (Head Assoc. Prof. Sv.Markov);

= Department of Modeling and Optimization of Bioprocess Systems, Central Laboratory for Biomedical Research, BAS (Head Prof. St.Tzonkov);

= Department of Automatics and Informatics, Technical University of Gabrovo (Head Assoc. Prof. R.Radev).

**International**

= Laboratory for Analysis and Architec-

ture of Systems-CNRS (Toulouse, France).

= University of Marseilles (France).

= Laboratory of Environmental Biotechnology-INRA (Narbonne, France).

**Mr. Simeonov has a number of publications, a selected list of which includes:**


• Simeonov, I., V. Momchev, D. Grancharov. Dynamic modeling of mesophillic anaerobic digestion of organic waste. Water Research, 1996, 5, 30, 1087-1094.

• Stoyanov, S., I. Simeonov. Robust compensator control of continuous fermentation processes. Bioprocess Engineering, 1996, 15, 6, 47-51.

• Simeonov, I. Mathematical modeling and parameters estimation of anaerobic fermentation process. Bioprocess Eng., 1999, 21, 4, 377-381.

• Simeonov, I. Modelling and control of biological anaerobic waste waters treatment processes (a review). Int. Journal "Archives of Control Sciences", 2001 (in press).

• Simeonov, I., J.-P.Babary, V. Lubenova, D. Dochain. Linearizing control of continuous anaerobic fermentation processes. Int. Symp. "Bioprocess Systems'97", Sofia (Bulgaria), Oct.14-16, 1997, III.21-24.

• Simeonov, I., D. Galabova. Investigations and mathematical modeling of the anaerobic digestion of organic wastes. 5Th Int. Conf. on Environmental Pollution, Thessaloniki, Greece), August 28 - Sept. 1,2000,285-295.

• Simeonov, I. Modelling and linearizing control of anaerobic wastewaters treatment processes. Int. Symp. on Applied Automatic Systems AAS'2000, Ohrid (Republic of Macedonia), 21-23 September,2000,1-6.

• Simeonov, I. Methodology for parameters estimation of non-linear models of anaerobic wastewaters treatment processes in stirred tank bioreactors, 5th Int. Symp. "Systems analysis and computing in water quality management - WATERMATEX 2000", Gent (Belgium), 18-20 Sept. 2000,8.40- 8.47.

• Simeonov, I. I. Queinnec, C. Gomez-Quintero, J. P. Babary. On linearizing control of wastewater treatment processes. Int. Conf. "Automatics et Informatics' 2000", v.3, Sofia (Bulgaria), Oct. 24-26, 2000, 84-88.

• Mitev, Vl. Decision expert system for cytomorphological investigations. Chemometr. Intel. Lab., 1997, 33, 41-47.

• Mitev, Vl., S. Popova. A model of yeast cultivation process based on morphophysiological parameters. Chemical and Biochemical Eng. Q., 1995, 9(3), 119-121.

• Popova, S., Vl. Mitev. Application of artificial neural networks for yeast cells classification. Bioprocess Eng., 1997, 17, 2, 111-113.

• Popova, S., Vl. Mitev. Two algorithms for image analysis and their application. Bioprocess Eng., 2000, 22, 4, 369-372.

# AWARDS

## FIRST PRIZE of the NATIONAL SCIENCE FUND

On December 27, 2005 the scientific collective body of the Solar-Terrestrial Influences Laboratory **"Acad. D. Mishev" at the Bulgarian Academy of Sciences** (STIL – BAS) led by research associate **Yordanka Semkova** was awarded **the first prize of the National Science Fund at the Ministry of Education and Science** for essential results achieved in developing of the research project "Investigation of the dose and flux dynamics in the "Liulin-5" dosimeter of in tissue equivalent phantom on board the Russian segment of the International Space Station (ISS)" during the Eleventh competitive session 2001–2005 of the Fund. The Minister of Education and Science - Assoc. Prof. Daniel Valchev handed the high award.

The aim of the research project is creation of a new active charged particle dosimetric telescope "Liulin-5" for fundamental and applied investigations in space connected with radiation fields characteristics and increase of radiation security of space crews.

The equipment and experiment "Liulin-5" have been developed by specialists from STIL "Acad. D. Mishev" – BAS and Institute of Medico-Biological Problems at the Russian Academy of Sciences (IMBP-RAS) for participation in the international space experiment MATROSHKA-R for radiation investigations on the International Space Station (ISS). The MATROSHKA-R project is being prepared and financed by research organizations and space agencies from Russia, ESA, Japan, Germany, Italy, Hungary, Austria, and Bulgaria. The aim of MATROSHKA-R project is to study the space radiation doses distribution at the sites of critical organs of the human body, using human body imitators called phantoms, and it is already being conducted on ISS.

A laboratory, technological and flying prototype units of the research equipment "Liulin-5" were developed and created during 2001 – 2005, and practical tests were performed in the Republic of Bulgaria and in Russia.

In 2005 calibration of "Liulin-5" was performed through direct exposure to heavy ion beams on the charged particle accelerator in Japan within the frame of the ICCHIBAN international experiment for calibration and intercalibration of space radiation dosimeters designed for investigations on the ISS.

In 2006 the dosimetric telescope "Liulin-5" will be delivered on board the ISS and mounted in the human phantom, thus experiments with it will start.

The topic "Investigation of dose and flux dynamics in the "Liulin-5" dosimeter of the tissue-equivalent phantom on board the Russian segment of the International Space Station" is included into the Scientific Cooperation Agreement between the Russian Academy of Sciences and BAS in the field of space research during the period of 2006 – 2008.

The results of the work on the project have been published in Bulgarian and international scientific publications with impact-factor and presented at a number of international and national congresses and conferences; they are included into two new national and international projects with participation of the team. All publications and reports are realized by international teams.

The work on the project is co-financed by the Bulgarian Academy of Sciences, National Science Fund at the Ministry of Education and Science, IMBP-RAS – Russia, CNR-IBEV – Italy, and NIRS – Japan.

## The Evrika Foundation
### awarded the following prizes for 2005:

"Evrika" awards are delivered to young people for achievements in science, for inventions with great social importance, for successful management of different business organizations that achieved high results in their sphere of activity. The annual awards stimulate bearers of the best achievements in respective spheres and make their talent, activity and achievements popular with the public. Public organizations and higher educational institutions nominate candidates for the awards, and special jury in the respective field makes the final choice.

**For achievements in science**

**DR. ROMAN KIRILOV ROMANSKY**

Aleksandrovska University Hospital, Clinic of Plastic Surgery

Dr. Roman Kirilov Romansky for defending the thesis "Microsurgical Aspects of Reconstructive Surgery in the Hand Area" in which modern treatment of traumatic hand injuries combined with irrevocable loss of tissues is investigated, in particular – microsurgical reconstructions by means of all kinds of free tissue transfer and finger microvessel transfer from the foot to the hand.

**For young inventor**

**DIMITAR NIKOLAEV KOLEV**

Dimitar Nikolaev Kolev from Sofia for the invention "Drying Installation for Obtaining Powdered Materials", with reduced fuel consumption and utilization of smoke gases. The invention can be applied both in ceramic industry and in other branches; it can be used for heating of plants without changing their heating system. Investigations of the built installation have proved 15.65% reduction of the fuel required for conduction of the process and the use of 1MW of the heat energy of the smoke gases for heating of the plant. On the basis of this invention an installation at the scattering dryer ATM25 on the territory of the plant for ceramic tiles "Khan Omurtag" – Shumen was designed and constructed.

**For young manager**

**ASEN NIKOLOV NIKOLOV**

Managing partner at "Farin" OOD

Asen Nikolov Nikolov for successfully implemented business models of management, good innovative and investment activities. Asen Nikolov's firm for grain crops achieved more than 60% increase of agricultural products export, 50% increase of mineral fertilizers sales and 29.95% increase in value of realized preparations for plant protection in comparison with the year 2004. During the recent two years the company invested:

1 000 000 euro for development of the filial transport company, 500 000 euro for renovation and construction of the service base, trade centre, new administrative building in the town of Dobrich, etc.

For excellent performance at the National competition
**honorary diplomas** are handed to:

- **Milena Dobranova** – total quality manager at "Food Industry BELLA";
- **Maria Ivanova** – marketing manager of "ZORA" chain of stores;
- **Andrey Bachvarov** –sales manager of the Swiss company SCIANT AG.

**For young farmer**

**ZAPRYAN NACHEV ZAPRYANOV**

Zapryan Nachev Zapryanov from the town of Stara Zagora for high quality of produced production, proper accomplishment of contracted obligations, the use of new equipment and his ambitions to construct a modern functional farm.

**A diploma for excellent presentation** at the competition among young farmers was handed to
**Nedyalko Todorov Slavov** from Rositza village, General Toshevo municipality.

## RECENT PUBLICATIONS OF BULGARIAN SCIENTISTS

## ARTICLES

**1.Title:** **Shallow Borehole Heat Exchanger: Response Test and Charging–Discharging Test with Solar Collectors.**
**Authors:** Georgiev, A.[1] *ageorgiev@gmx.de;* Busso, A.[2] ; Roth, P.[3]
**Source:** Renewable Energy: An International Journal, Vol. 31, 7 (2006 Jun.), 971-985,
**Document Type:** Article
**Author Affiliations:** [1]Department of Mechanics, Technical University of Sofia, Branch Plovdiv, Bulgaria
[2]Department of Physics, FaCENA, UNNE, 3400 Corrientes, Argentina
[3]Department of Mechanical Engineering, UTFSM, Valparaiso, Chile
**ISSN:** 0960-1481

**2.Title:** **Problems on Small– and Medium–sized Enterprises Development in Republic Bulgaria.**
**Authors:** Manoilova, Temenuga[1] *tmanoilova@hotmail.com*
**Source:** International Journal of Entrepreneurship & Innovation Management; Vol. 6,1/2, (2006), 7-7
**Document Type:** Article
**Author Affiliations:** [1]Energoproekt - JSC, 51, James Boucher Blvd., Sofia 1407, Bulgaria.
**ISSN:** 1368-275X

**3.Title:** **Mechanism of the Oxygen Cycle Reactions Proceeding at the Negative Plates of VRLA Batteries.**
**Authors:** Pavlov, D.; Kirchev, A.[1]; Monahov, B.[1]
**Source:** Journal of Power Sources; Vol. 144, 2, (2005 Jun.) 521-527,
**Document Type:** Article
**Author Affiliations:** [1]Institute of Electrochemistry and Energy Systems (former CLEPS), Bulgarian Academy of Sciences, Sofia 1113, Bulgaria
**ISSN:** 0378-7753

**4.Title:** **Hybrid Solar Collector.**
**Authors:** Lazarov, V.[1] *vl;* Schaeffer, Chr.[2] ; Shishkov, M.[1]; Ivanova, M.[2]
**Source:** Journal of Materials Processing Technology; Vol. 161,1/2, (2005 Apr.) 229-233
**Document Type:** Article
**Author Affiliations:** [1]Faculty of Electrical Engineering (bl.12), Technical University – Sofia, 8, Kl. Ohridski Blvd., 1000 Sofia, Bulgaria
[2]Laboratory of Electrical Engineering Grenoble-ENSIEG-National Polytechnic Institute of Grenoble BP 4638402 St. Martin-D'Heres, Grenoble, France
**ISSN:** 0924-0136

| | |
|---|---|
| **5.Title:** | **Investigation of Structural Properties of Poly-Si Thin Films Obtained by Aluminium Induced Crystallization in Different Atmospheres.** |
| **Authors:** | Dimova-Malinovska, D.[1] *doriana@phys.bas.bg;* Grigorov, V.[2] Nikolaeva-Dimitrova, M.[1]; Angelov, O.[1]; Peev, N.[3] |
| **Source:** | Thin Solid Films; Vol. 501,1/2, (2006 Apr.), 358-361, |
| **Document Type:** | Article |
| **Author Affiliations:** | [1]Central Laboratory for Solar Energy and New Energy Sources, BAS, 72, "Tzarigradsko chaussee" Bvld, 1874 Sofia, Bulgaria<br>[2]University of Chemical Technology and Metallurgy, 8, "Kliment Ohridski" Blvd., 1756 Sofia, Bulgaria<br>[3]Institute of Solid State Physics, BAS, 72, "Tzarigradsko chaussee" Blvd., 1874 Sofia, Bulgaria |
| **ISSN:** | 0040-6090 |

| | |
|---|---|
| **6.Title:** | **Magnetic Mineralogy and Grain-size Dependence of Hysteresis Parameters of Single Spherules from Industrial Waste Products.** |
| **Authors:** | Jordanova, Diana[1] *vanedi@geophys.bas.bg;* Jordanova, Neli[1] Hoffmann, Viktor[2] *viktor.hoffmann@uni-tuebingen.de* |
| **Source:** | Physics of the Earth & Planetary Interiors; Vol. 154, 3/4, (2006 Mar.), 255-265, |
| **Document Type:** | Article |
| **Author Affiliations:** | [1]Geophysical Institute, BAS, Acad. G. Bonchev Str., Block 3, 1113 Sofia, Bulgaria<br>[2]Institute of Geosciences, University Tuebingen, Sigwartstrasse 10, 72076 Tuebingen, Germany |
| **ISSN:** | 0031-9201 |

# EVENTS

## Round Table Meeting "Problems of Mobility and Career Development of Scientists in Bulgaria – Possible Measures for Transforming the Phenomenon "Brain Drain" into "Brain Circulation" (Sofia, April 13, 2006)

One of the main trends of development since the beginning of the century is connected with awareness that highly qualified personnel in the field of science and research has the leading role in meeting the new challenges of the EU. Nevertheless, great part of scholars chooses to work in non- European countries. This phenomenon called "brain drain" is well known in Bulgaria as well.

Many young Bulgarian researchers take their road to the West, mostly to America, in search for better work and professional development. The Union of Scientists in Bulgaria evaluates that during the 1990s 65% of university graduates (i.e. about 300 000 persons) left the country. This fact seriously threatens the future of the "human capital" in the field of science and technology (S&T) in Bulgaria, as at present (2005) 73% of the professors are over 60 years old, and 47% - over 65. It is absolutely necessary to attract young and talented people into the sphere of S&T, as well as to introduce measures for encouraging young scientists and supporting their career development. From the beginning of January, 2006 the University of Pisa starts its work on the Twinning Light Project "Implementation of the National Strategy for Scientific Research" dealing with creation of strategies against the "Brain Drain" phenomenon. Within the framework of this project the Bulgarian Ministry of Education and Science and the University in Pisa (contact person: nikolaus.muellner@univie.ac.at) organized a Round Table meeting "Problems of Mobility and Career Development of Scientists in Bulgaria – Possible Measures for Transforming the Phenomenon "Brain Drain" into "Brain Circulation" on April 13, 2006 in Sofia.

More than 50 representatives from about 30 organizations took part in the Round Table meeting, including the European Commission, leading universities, Bulgarian Academy of Sciences, National Centre for Agrarian Sciences, researchers, representatives of the industry and other interested organizations from Bulgaria, Italy and Austria. The following key topics connected with researcher's career development and job satisfaction were discussed:

- Mobility (international and interdisciplinary)
- Opportunities for researcher's career development (job opportunities)
- Scientists' salaries – financial state and social prestige
- Working conditions (physical – e.g. infrastructure; organizational, etc.)
- Quality of research and education (technical/professional knowledge and abilities of scientists).

Additional topics of the Round Table were as follows:

- The attitude of SMEs and big companies to scientific research and its development
- The experience of other European countries regarding the "Brain Drain" phenomenon
- Demand for specialists in particular fields of economy in Bulgaria

The organizers of the event summarized the conclusions and deductions of the first Round Table meeting held in December 2005,

made reports on developments during the past period and pointed out the main challenges up to now as well as the tasks to be solved after Bulgaria joins the European Union. The representative of the European Commission presented the Commission's point of view, measures realized within the 6th Framework Program as well as thematic areas underlying in the priorities and budget of the 7th Framework Program. There was mentioned the budget for the 7FP fixed by the European parliament at not more than 50 billion euros. The participants shared their experience on the problems of mobility and career development of scientists in Bulgaria and called for more active support from the legislative and executive power before joining the EU. Special attention was paid to intra-disciplinary mobility between the academic community and business, political and market factors of influence. Problems of supply and demand of researchers in Bulgaria were investigated, as well as the share of the private sector in these processes and their present state in the EU and USA. Final summary of recommendations, suggestions and conclusions will be made when the project is over, and till then the organizers provide real possibility for all interested researchers, organizations, SMEs and individuals to take part in the discussions and submit their particular recommendations to the on-line forum (http://twinning.tacis.ing.unipi.it/), which will function till October 2006.

**11–14 May 2006**
3rd International Conference of ASECU
**Regional Economic Cooperation in Southeastern Europe**
D. Tsenov Academy of Economics, Svishtov, Bankya - Sofia
Address:
Mrs. Dimka Kostadinova,
2, Em. Chakarov St., 5250 Svishtov, Bulgaria
Office "International Relations and Projects"
Phones: +359 631 6 04 50; +359 631 6 09 78
Fax: +359 631 6 04 72
E- mail: mvip@uni-svishtov.bg

**17 – 18 May 2006**
Jubilee Conference
**"125 Years "Nikola Vaptsarov" Naval Academy" 1881 – 2006**
"N. Y. Vaptsarov" Naval Academy, Varna
Co-organizer
BULGARIAN MARITIME TRAINING CENTRE
Address:
"N.Y.Vaptsarov" Naval Academy,
for the Conference
73, "Vassil Droumev" Str., 9026 Varna
Phones: +359 52 552 228; +359 52 552 374;
Fax: +359 52 303 163
E-mail: public-rel@naval-acad.bg
info@naval-acad.bg
www.naval-acad.bg

**18 – 19 May 2006**
National Sympozium On
**Steel, Timberland Composite Structures**
University of Architecture, Civil Engineering and Geodesy
Department of Steel and Timber Structures,
Faculty of Structural Engineering
Sofia, Bulgaria
Address:
Dr. Borislav Belev
Dept. of Steel and Timber Structures
1, Chr. Smirnenski Blvd., Sofia 1046
E-mail: belev_fce@uacg.bg,
racheva_fce@uacg.bg

**31 May – 3 June 2006**
IV-th International Conference
**"Challenges in Higher Education and Research in the 21st Century"**
ENGLISH LANGUAGE DEPARTMENT
of ENGINEERING at the TECHNICAL UNIVERSITY of SOFIA
Sozopol, Bulgaria
Address:
Lubomir Dimitrov, Prof. Ph.D
English Language Department of Engineering,
Technical University of Sofia,
8, Kliment Ohridski Blvd. Sofia 1756, Bulgaria
Phone: +359 2 965 2996
Fax: +359 2 965 2447

E-mail: lubomir_dimitrov@tu-sofia.bg,
Office: 4421

**1 – 2 June 2006**
NATIONAL CONFERENCE WITH INTERNATIONAL PARTICIPATION
**"ELECTRONICA'2006"**
Union of Electronics, Electrical Engineering and Communications and
Technical University of Sofia
National Home of Science and Technique
108, "Rakovsky" Str., Sofia
Address:
Union of Electronics, Electrical Engineering and Communications
108, "Rakovsky" Str., 1000 Sofia,
Phones: +359 2 987-97-67 and
986-52-00, Fax: 987-93-60,
E-mail: ceec@mail.bg,
electronica2006@gmail.com
www.ceec.hit.bg,

**2 June 2006**
International Forum
**„Academic Partnership for Human Resource Development –**
**Specific Characteristics, Experience and Capacity of the Universities in Southeast Europe and the Balkans"**
Varna Free University "Chernorizets Hrabar"
Address:
Varna Free University "Chernorizets Hrabar"
E-mail:projects@vfu.bg

**7–9 June 2006**
International Conference
**Energy Efficiency and Agricultural Engineering**
"Angel Kunchev" University of Rousse
Address:
Secretary: T.Grozdeva
8, Studentska Street, 7017 Rousse, Bulgaria
Phones: +359 82 451 092
Fax: +359 82 451 092; +359 82 455 145
E-mail: ird@ru.acad.bg, mihailov@ru.acad.bg,
vezirov@ru.acad.bg

**9–11 June 2006**
International Scientific Conference
**The Accession of Bulgaria to the European Union – Challenges, Problems, Trends**
Burgas Free University
Address:
62, San Stefano Street, 8001 Burgas, Bulgaria
Phones: +359 56) 900 400;
+359 56 900 508, +359 56 900 449
Fax: +359 56 / 813 905
E-mail: konferencia@bfu.bg

**10 –16 June, 2006**
32-nd International Conference
**Application of Mathematics in Engineering and Economics**
Faculty of Applied Mathematics and Informatics, TU-Sofia
Sozopol, Bulgaria
Address:
E-mail: mtod@tu-sofia.bg, andru@tu-sofia.bg

**12–16 June 2006**
6th International Scientific Conference
**Modern Management of Mine Producing, Geology and Environmental Protection – SGEM**
Ministry of Environment and Water
Albena Complex
Address:
Secretariat Bureau
14, "Kliment Ohridsky" Blvd., 1797 Sofia
Phones: +359 2 975 3982
Fax: +359 2 817 2477
E-mail: sgem@sgem.org or sgem@stef92.com,
www.sgem.org

**28 June 2006**
International Scientific Conference
**"Informatics in the Scientific Knowledge 2006"**
Varna Free University "Chernorizets Hrabar"
**Address:**
E-mail: conf_inf2006@vfu.bg
http://hs19.iccs.bas.bg/vfu

**29 June – 1 July 2006**
XLI International Scientific Conference on
**Information, Communication and Energy Systems and Technologies**
Faculty of Communications and
Communication Technologies,
Technical University of Sofia
Sofia, Bulgaria
Address:
8, Kliment Ohridski Blvd.
Phones: +359 2 965 3095; +359 2 965 2278
Fax: +359 2 965 3095
E-mail: icest@tu-sofia.bg, dcd@tu-sofia.bg