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History of the Scientific School of Z. A. Mansurov at the Institute of Combustion Problems in Almaty

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Abstract: *The article discusses the origins, formation, and development of the scientific school of chemical physics and nanotechnology in Kazakhstan. The authors describe the achievements of a scientific school that is on par with the best of its kind locally and globally, adding new competitive results of practical relevance to the economic development of the country. The article also highlights the special role of the outstanding scientist Zulkhair Aimukhametovich Mansurov in the development of the methodological foundations of the scientific school, the targeted training of the scientific personnel in the priority areas of the development of Kazakhstani chemical physics, and the creation of nanoscale materials for multifunctional purposes. Also, the main principles of the philosophy of Mansurov's scientific school are presented.*

Keywords: *chemical physics, nanotechnology, origins, scientific school*

General background

Professor Zulkhair Aimukhametovich Mansurov.

In spring 1988, Professor Georgii Ivanovich Ksandopulo, doctor of chemical sciences and winner of the State Prize of the Republic of Kazakhstan, took the initiative in establishing the Kazakh scientific-technical centre for self-propagating high temperature synthesis (Kaz ISTC for SHS) based on the Department of Chemical Kinetics and Combustion of the Kazakh State University named after S. M. Kirov (now Al-Farabi Kazakh National University). The centre was later renamed the Institute of Combustion Problems under the administration of the scientific committee of the Ministry of Education and Science of the Republic of Kazakhstan. It is within the walls of this institute that the scientific school of Z. A. Mansurov originally came into being.

The formation of Mansurov's scientific school started in his student years under the supervision of Georgii Ksandopulo. When Mansurov was a second-year student, Ksandopulo saw in him a future scientist, successor and creator of his own scientific school. He suggested that Mansurov studied the kinetics of hydrogen oxidation, and already back in 1978 recommended that he should make a report on the structure of the cool flame of diethyl ether at the Department of Combustion of the USSR Academy of Sciences, at the time led by Ya. B. Zeldovich, before the luminaries of the Soviet scientific school of the Nobel Prize laureate N. N. Semenov, who highly appreciated Ksandopulo's 1994 doctoral dissertation 'The structure of the flame front and the inhibition of the combustion process.'

In 1973, Mansurov defended his graduate thesis under the supervision of Professor Ksandopulo and evolved as a scientist in the field of chemical kinetics and combustion. In 1990, he defended his doctoral dissertation at the Institute of the Structure of Macrokinetics of the USSR Academy of Sciences (Chernogolovka, Moscow region). His supervisor's direct communication with such eminent scholars in the field of combustion as the Nobel Prize laurate N. N. Semenov, Li Yang, academicians Ya. B. Zeldovich, V. N. Kondratiev, A. G. Merzhanov, and others, had a great influence on Mansurov's formation as a scientist.

The high level and results of the scientific work contributed to organizing in Almaty the 6th Union-wide Symposium on Combustion and Explosion (1980), the Union-wide Symposium on Macroscopic Kinetics and Chemical Gas Dynamics Councils of the USSR Academy of Sciences and Union-wide meetings on combustion processes and self-propagating high temperature synthesis, and the establishment of the Institute of Combustion Problems under the Kazakh National University. In 1992, under Ksandopulo's lead, Mansurov's scientific team was awarded the State Prize of the Republic of Kazakhstan for the series *Fundamental Research into the Chemical Foundations of Combustion*.

From 1998 until now, Professor Zulkhair Aimukhametovich Mansurov, doctor of chemistry and winner of the State Prize of the Republic of Kazakhstan, Ksandopulo's student and the founder of the scientific school of chemical physics on combustion problems, has been the director of the Institute of Combustion Problems. Among the research carried out in the synthesis of nanomaterials and nanotechnology under the guidance of Professor Mansurov is the production of fullerenes, nanotubes, superhydrophobic carbon black, graphene in flames, and hydrocarbon fibers using the method of electrospinning as well as the synthesis of carbonized nanostructured materials based on plant raw materials and their practical usage for the ecological purposes, medicine and agricultural economics, which all are evidence of the formation and development of the school in the field of nanotechnologies (Krivoruchenko, 2011). Today, Mansurov's scientific school is represented by 50 doctors of science, candidates of science and PhD holders who actively carry out research of the scientific school, and present their research results at international conferences. The head of the scientific school himself often speaks at various international scientific forums and conferences (e.g., 'Carbon' and 'Combustion processing').

It should be noted here that the development of chemical physics and its origins in Kazakhstan are associated with the research of hydrocarbon flames, which was started at the Kazakh State University in the 1960s under Ksandopulo's lead with the active support of B. A. Beremzhanov, dean of the Faculty of Chemistry and a corresponding member of the Academy of Sciences of the Kazakh SSR, Academician of the Academy of Sciences of the Kazakh SSR M. I. Usanovich and Rector and Academician U. A. Dzholdasbekov. Initially, these priority studies were carried out within the framework of the Department of Chemical Kinetics and Combustion, which in 1998 was renamed the Department of Chemical Physics, with Mansurov acting as head of the department. In essence, this was not just a renaming of the department, but a significant expansion of research into the chemical foundations of combustion processes. It is important to emphasize Mansurov's role in this, as he initiated and developed a brand-new promising path of studies on combustion strategies, first laid down by his teacher. It must be noted that Ksandopulo's research was at the forefront of breakthrough fundamental studies on the problems of self-propagating high-temperature synthesis (or SHS), carried out in the Soviet Union under the guidance of academicians Yakov Zeldovich and Alexander Merzhanov, the latter from the scientific school of the Nobel laureate Academician N. N. Semenov.

Research into SHS processes has opened up new horizons of knowledge and practical applications. Previously unexplored systems, phenomena and processes, and the various scientific problems, tasks and possible practical applications that have emerged in the study of these, have become the desired object of experimental diagnostics and theoretical modeling. History of science shows that the personality of a great researcher lies precisely in the ingenious foresight and prediction of potential development and topical research directions. This is what happened in this case, i.e., during the origination and formation of the Kazakh scientific school of chemical physics. Initiation and development of combustion processes and self-propagating high-temperature synthesis by Academician Merzhanov first led to the establishment of a SHS center and the development of combustion theory and SHS technology in Kazakhstan, and then the founding of the Institute of Combustion Problems (ICP) (Grezneva, 2003, p. 69).

International recognition to Mansurov's active and fruitful scientific activity contributed to the founding of the *Eurasian Chemico-Technological Journal*, published in English, of which he is the editor-in-chief. The main aim of the journal is to intensify the exchange of information between scientists from the Commonwealth of Independent States (CIS) and Eurasian countries. The journal publishes articles on topical problems of organic synthesis, physics and chemistry of the properties of oil, coal, unconventional techniques of processing raw hydrocarbon materials (plasma chemistry, combustion, radiation chemistry, and others), also thermodynamics and thermochemistry. The *Eurasian Chemico-*

Technological Journal is the only periodical published in Kazakhstan that is abstracted in the Scopus database of Elsevier publishing house.

The Institute of Combustion Problems of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan is a leading research institute in the field of chemical physics, combustion processes, plasma chemistry, SH synthesis, mechanochemistry, materials science, nanomaterials, and nanotechnologies. The institute has modern instrumental and computer facilities to carry out scientific research at a high scientific level. Since 2000, the institute organizes in Almaty annual international symposia 'Physics and Chemistry of Carbon Materials / Nanoengineering' (held once every two years) and since 2001 'Combustion and Plasma Chemistry' (held once every two years). The institute's main scientific directions, in both fundamental and applied studies, are the following:

- Study of the chemistry and physics of combustion processes in gaseous and condensed phases;
- Study of gas flame structure;
- Research of the problems of self-propagating high-temperature synthesis for the creation of new and improvement of traditionally produced materials;
- Synthesis of high-temperature electrically conductive ceramic materials;
- Research of the regularities of obtaining composite ceramics based on carbides, silicide, borides of transition materials under SHS conditions;
- Development of nanotechnologies and production of carbon nanostructured multifunctional materials (sorbents for water purification from heavy and radioactive metals, extraction of noble metals, hem sorbents, etc.);
- Research and processing of petroleum gases using the principles of technological combustion;
- Development of new nanomaterials with the desired properties;
- Development of pure materials and alloys with the desired properties and structure;
- Development of methods for processing mineral and technogenic raw materials using the principles of technological combustion;
- Development of energy-intensive and ecologically friendly technologies;
- Fundamental principles of development and deep complex processing of mineral raw materials to obtain products of increased marketability;
- Plasma chemistry.

The Institute of Combustion Problems produces materials for industrial enterprises—welding electrodes, acid-resistant powder for thermal power plants, "Furnon", a new material in refractory practices, fuel briquettes, and fire-extinguishing powders—in its own production facilities. The scientific achievements of the institute have been presented at international exhibitions in San Diego, US (December 1995), India (January 1996), and Geneva, Switzerland (1989), where the refractory material "Furnon" won a silver medal.

Mansurov is known in the scientific community not only as an experimenter, a pioneer who laid the scientific foundations of a new direction in science, but also as a teacher, organizer of the educational process at the oldest university in Kazakhstan—Al-Farabi Kazakh National University. From 1979 to 1987, as head of the laboratory of physical and chemical research methods, Mansurov took actively part in the work of the department and lectured on special courses 'Theory of Combustion', and 'Kinetics of Gas-Phase Reactions'.

Mansurov himself regards highly his teacher and colleagues at the university, recognizing the great work of the department staff under the Ksandopulo's lead. In the first decade, Ya. B. Kolesnikov, A. A. Sagindykov, V. V. Dubinin, M. B. Ismailov, and V. A. Zavadsky made a significant contribution to the development of the course of physical methods of research and special courses on combustion (Suleimenov, Karabayev & Dzhumabekov, 2011, pp. 63–67).

Scientific school: the concept

In science studies, the term 'scientific school' tends to have different semantic shades. Each scientific school contributes to the development of a new idea in a scientific field. Scientific schools are characterized by the following features: initiative, independence, internal impulse for development, purposefulness, persistence of convictions, and dissatisfaction with what has been achieved. For a scientific school, scientific self-determination, self-identification of a member of the school, identification and strengthening of his social role in it, and the design of the research activity of each as part of the whole are extremely important. The analysis shows that the term 'scientific school' is mainly used in three categories:

- Formal association, scientific-educational organization of various status (university, department, faculty, research institute, laboratory);

- The research (creative) team not necessarily having formal affiliation with any structural unit of the university or research institute;
- The direction of science that integrates the interests of a group of researchers. (Mansurov, 2016, pp. 32–35)

Thus, even such a brief discussion of the basics of the term 'scientific school' reveals that it is a circle of highly qualified specialists, united by a single scientific problem, who are actively maintaining creative ties with each other and working according to a unified methodology of the founder of a new scientific direction. It is evident that the scientific leader who has proposed the new direction in science, the team he leads, and the result of a successful development of fundamental and applied tasks, all constitute a scientific school in the corresponding field of knowledge. While maintaining continuity, deepening the scientific process in accordance with the principle of the philosophical spiral of development, in which each new turn expands the horizon of knowledge, the scientific school becomes widely known in the scientific community, and its leader will have the right to be called a teacher.

The foundations of the original Kazakhstani scientific school of chemical physics and nanotechnology

Mansurov's contribution to the formation of the Kazakhstani school of chemical physics and combustion studies is significant. His scientific research focuses on the study of the kinetics, which formed the basis of his Candidate's thesis and is represented in his works on the kinetics of the interaction of atomic hydrogen with inhibitors, and the mechanism of combustion of hydrocarbons and the structure of cool and sooty flames: the formation of catalytic carbon and its applied aspects. Mansurov was the first to discover hydrogen atoms in cool flames of hydrocarbons and determined oscillation conditions of temperature and concentration of radicals in cool flames of butane and hexane. He proposed a phenomenological model to clarify the oscillation condition of hydrocarbon oxidation and established the impact of the electric field on the sizes of spot particles during the combustion of sooty flames of propane. The structure of the front of cool flames of pentane and isopentane was studied in detail (as part of the contract with the Livermore Research Laboratory in the United States). Works on low-temperature, cool-flame spot formation during combustion of rich hydrocarbon flames, published in 1987, can thus be regarded as the basis for the founding of the original Kazakhstani scientific school of chemical physics and nanotechnology. The conditions of spot formation with and without application of an electric field were studied. It was found that the sizes can be controlled by applied voltage, with particle diameters decreasing 2–5 times. The considerable interest of the scientific and technology community in exploring methods for designing, structuring and characterizing nanoscale systems was due to the diversity and uniqueness of the options for their practical application. The small size of structural components—usually up to 100 nm—determines the distinction between the properties of nanomaterials from their massive analogs.

The term 'nanotechnology' implies the technological processes or a set of methods for creation and use of nanoscale materials or material consisting of nanoscale components, equipment and devices, as well as processes of obtaining nanomaterials. Thus, nanotechnology stands for the production of nanostructures using atomic-molecular elements and the synthesis of larger systems from them. The term 'nanotechnology' was first used by the Japanese researcher Norio Taniguchi in 1974. However, in the Soviet Union, the term 'materials science' was used. In the recent decade, in many industrially developed countries, the scientific-technical trend 'nanoparticles – materials – technologies – devices' has been established and it is becoming the fastest growing in terms of funding.

National as well as international companies are involved in the production of nanomaterials and large-scale research in this field. The term nanotechnology and the technology for creating nanoscale materials for multifunctional purposes is thus not a choice of fashion, but an objective development and advancement of fundamental and applied investigations in the field of nanomaterials and nanotechnology when studying combustion processes. Thus, at the Institute of Combustion Problems, original results on the development of carbon nanomaterials for various functional purposes were obtained by the synthesis of fullerenes in a flame, the synthesis of carbon nanotubes in a flame, the synthesis of a superhydrophobic carbon surface under the conditions of combustion, the SH synthesis of nanosized materials, and the synthesis of nanosized catalysts for carbon dioxide conversion of methane into synthesis gas.

At the same time, in the field of practical research of the combustion process, two very important developments can be distinguished—those pertaining to energy and those pertaining to chemical technology. In the first case, the heat of combustion reactions is used and very often, but not always, the energy of expanding gaseous products. In the second case, the combustion product itself, which is the target substance of the chemical technological process, is of interest. The main feature of combustion-based processes is that the target product is formed as a result of a combustion reaction that occurs spontaneously at high temperatures at a high rate without external energy consumption, i.e., due to its own heat release.

These directions of research at the Institute of Combustion Problems, which determine the current state of development in combustion processes, form the basis of the original Kazakhstani school in the field of chemical physics and nanotechnology (Merzhanov, 2007, p. 200).

The main results and achievements of Mansurov's school

The developed concepts of combustion wave made it possible to establish the theoretical basis of new original technologies based on combustion processes: flame-initiated pyrolysis of hydrocarbons with the aim to obtain olefins, synthesis of target products under the conditions of cool flames, development of effective inhibitors of combustion of gas and condensed systems, and effective refractories "Furnon". The results have found application in a number of enterprises in Kazakhstan, the Soviet Union, and other countries.

The investigations carried out by Mansurov in recent years are at the cutting edge of science. They cover the generation of fullerenes, nanotubes, superhydrophobic spot, graphenes in flames, carbon fibers using the method of electrospinning. Also, the synthesis of carbonized nanostructured materials based on plant raw materials and their practical applications for ecological purposes, medicine, and agriculture are evidence of the formation and development of the scientific school in the field of nanotechnologies.

The results of the research are published in the monograph *Formation of PAHs, Fullerenes, Carbon Nanotubes and Spot in Combustion Processes*, the manual *Synthesis and technologies of nanostructured materials*, and are reported at international conferences and issued in high impact-factor journals (Kapitsa, 1981, p. 496).

Among the current directions, the following are of priority: soot-forming flames as chemical reactors; thermal processing of oil-contaminated soils; utilization of used car tires using cry detonation and pyrolysis technologies, nanocarbon materials; mechanochemical encapsulation of quartz particles in metal-carbon shells manufacturing of carbon-graphite cathodes for chemical current sources; carbon-containing refractories; and carbonization of plant raw materials.

1. Soot-forming flames as chemical reactors

The potential of using low-temperature combustion conditions for the production of different polycyclic aromatic hydrocarbons (PAHs) with a number of important properties and soot with the desired structural parameters has been granted a diploma patent for a scientific discovery. The study highlights the phenomenon of cool-flame low-temperature soot formation. In the fluorescence spectra of soot, intensive bands with a clear vibrational structure can be observed. It is argued that in the process of soot formation, a synthesis of polyaromatic luminophores with high quantum outputs (in the blue and green) regions of the spectrum takes place. PAHs tend to form a liquid crystalline phase, thus making it possible to obtain mesophase pitches on their basis. For the first time, a region of manifestation of an optically anisotropic phase was found at an anomalously high temperature from 480 to 510 °C, providing the potential of creating a material for producing pitches with a high mesophase content.

When studying the effect of an electric field on the processes of soot formation in benzene-oxygen flame, it was argued that the increase in the power of the discharge applied to the flame results in the increase in the efficiency of fullerene formation maximum yield of C60 fullerenes increasing to 16% in regard to the whole mass of soot formed was found in the region of the glow discharge.

Research on the synthesis of nanoparticles in hydrocarbon flames with catalyst additives has been started.

2. Thermal processing of oil-contaminated soils

An installation for gas-flame processing of oily soils has been developed and built. The installation allows to separate oil and oily soil, while the cleaned soil can be further used for preparation of cold asphalt concrete inroad construction (see Points 14 & 15 below). Oxidation of the organic part of oil wastes was carried out in a laboratory oxidizing column in a periodic duty at 250 °C and consumption of air of 2 l/min per 1 kg of feedstock. During its oxidation, construction bitumen BN 90/10 and road asphalt BND 40/60 were obtained.

3. Utilization of used car tires using cryo detonation and pyrolysis technologies

The researchers also developed a method of cryo detonation destruction. This involved two main operations—cooling the tire to a temperature at which it loses its elastic properties, and detonation destruction. The rubber remaining on the metal cord is subjected to pyrolysis.

4. Nanocarbon materials

Carbonized materials were obtained on the basis of local clays and mining waste: chromite and bauxite sludge, agricultural waste (walnut shells and grape seeds) and their use in various applied aspects. The obtained adsorption-catalytic systems find practical application for purification of oil from sulfur-containing compounds, purification of water from organic compounds and heavy metal ions, purification of air from SO_2, and for obtaining improved types of refractories as carriers of catalysts for hydrocarbon conversion reactions.

5. Mechanochemical encapsulation of quartz particles in metal-carbon shells

A basic role of quartz as a matrix element in the formation of the structure and functional properties of composite systems in common was investigated. A single process for synthesizing magnet adsorbents based on mineral and technogenic raw materials was developed. The potential for regeneration and reuse of the material, which is economically feasible for large-scale application when solving ecological problems in the field of environmental protection, was demonstrated. Its morphology and transformation, depending on the conditions of mechanochemical processing, was registered by electron microscopic studies.

After mechanochemical treatment, a quartz molecule is indeed encapsulated in a shell immovably bound to the surface of the molecule.

6. Manufacturing of carbon-graphite cathodes for chemical sources of current

Carbon materials based on apricot stones have been tested as a cathode material in the research laboratory of the Tokyo Institute of Technologies, and high cycling characteristics have been stated when combined with a lithium (Li) cathode at high currents.

The specific capacity of 200 mA h/g is somewhat lower than that of natural graphite, but it is more stable in different electrolytes, including propylene carbonate, in which natural graphite does not work.

7. Carbon-containing refractories

The introduction of chromite sludge increases the density and mechanical strength in comparison with the "Furnon-3KhP" refractory, slightly increasing the refractoriness. The improvement in the physical and mechanical properties of carbon-containing refractories based on clay and chromite sludge is explained by the formation of fibrous carbon and metal carbides. The resulting refractory materials have high slag resistance, which makes it possible to predict their use in metallurgical processes for the production of precious metals.

8. Carbonization of plant raw material

Raw materials based on the processing of agricultural products refer to quickly renewable sources and are more ecologically friendly. During carbonization (pyrolysis in an inert atmosphere) of samples of walnut shells, apricot and grape seeds, the main weight loss occurs in the temperature range of 200–500 °C. At 500 °C, about 50% of the mass is lost in 1 hour, and finally, at 950 °C, the loss reaches about 75%. In the laboratory of nanocarbon materials named after R. M. Mansurov, a carbon-mineral sorbent (SKRS-2) was synthesized based on carbonized plant raw materials, containing carbon and silicon oxide and having a nanoscale morphology.

The presence of these components gives this material specific and unusual properties. If carbon is a hydrophobic material and silicon oxide is hydrophilic, then a completely new combination of hydrophobic-hydrophilic properties arises. It is these unusual properties that make it possible to propose this material as a unique nanostructured sorbent for separation of bioorganic compounds, in particular, the release of a biostimulator—fusicoccin. SKRS-2—was synthesized by carbonization of plant raw materials in a rotating steel reactor in the temperature range of 300–8000 °C for 5–60 minutes in an inert medium.

It was found out that the use of fusicoccin increases the germination of wheat seeds by 17% and increases the yield by 15%.

9. Synthesis of nanostructured sorbents from natural plant materials

In the institute's laboratory of carbon nanomaterials, an installation was developed for the synthesis of a carbon sorbent based on carbonized plant raw materials, which has a nano-structural morphology. The obtained sorbent is used for protein chromatography and has excellent molecular sieve characteristics. It is versatile and can separate proteins and peptides of different molecular weights. The sorbent has high mechanical strength—it can be used for years.

The same technology was used to obtain a sorbent for chromatographic decontamination of fusicoccin. The sorbent is created by carbonization of a few sorts of plant raw materials using special technological conditions. Biologically active substances obtained in the form of an extract from agrarian seeds by their germination and homogenization with cooled ethanol are centrifuged and passed through a column with a nanostructured sorbent.

Then, multistage elution with ethanol of different concentrations is carried out, followed by analysis of the product.

Growth stimulator "Fusicoccin" significantly increases seed germination on saline soils. Field trials have shown that wheat treated with this biostimulant solution ripens 15 days earlier.

10. Fullerene synthesis in a flame

The research revealed an increase in its temperature only in the upper pact by 50 °C, and spreads at a distance of 1–1.5 cm. It was found that intensification of the fullerene formation takes place at the interface between the acetylene-oxygen and benzene-oxygen flames. The positive impact of the acetylene flame consists in an increase in the temperature of the reaction zone of the most benzene-oxygen flame by 50 °C, in an increase in the degree of ionization, as well as in an intensive transformation of PAHs in the benzene-oxygen flame into fullerenes.

11. Synthesis of carbon nanotubes in a flame

The most promising method for the production of carbon nanotubes, according to the opinion of many authors, is the flame method. When using a flame for the synthesis of carbon nanoparticles, part of the fuel is consumed for heating the mixture, and some is used as a reagent, this being more economical in comparison with the methods based on the use of electricity, pyrolysis of hydrocarbons. The obtained samples contain soot agglomerates, among which metal particles are observed.

It was found that, under certain experimental conditions, formation of well-ordered braids of carbon nanotubes is possible.

12. Synthesis of a superhydrophobic carbon surface under the conditions of combustion mode

An experimental study of the deposition of soot on a silicon and nickel substrate during the combustion of a propane-oxygen mixture was carried out.

Electron microscopic images of soot taken from the surface of the substrate showed the presence of nanobeads, the concentration of which predominates in the brown zone. In this case, the average size of soot particles increases from the center to the edge.

When a voltage of 1 kV or more is applied, the flame visually undergoes changes, it becomes brighter, jump of spark discharge is observed, and copious formation of soot occurs on the substrate. Without application of an electric field, the flame spreads over the surface of the substrate. With application of an electric field, the flame spreads in the form of a cylinder with a diameter of 1.5 cm. In this case, the scoot surface is uneven. Application of an electric field increases the thickness of the carbon hydrophobic layer and harrows this area.

13. SH synthesis of nanoscale materials

Production of silicon nanopowder is an important task for different applications, including microelectronics, solar power and rocket fuels. In this work, such a product was obtained by the method of self-propagating high-temperature synthesis (SHS), which is an elective technology for the production of different materials, distinguished in its simplicity and low power consumption.

14. Synthesis of nanosized catalysts for carbon dioxide conversion of methane to synthesis gas

Due to the annual reduction of oil reserves in the world, there is an urgent need to find new sources of alternative pure fuels. It is known that dimethyl ether, obtained from synthesis gas by conversion of carbon dioxide to methane, can act as such a fuel.

A 5x5 cm glass cloth was impregnated with a solution of nitrate salts of cobalt, nickel and glycine, taking into account its moisture capacity, then the sample was air-dried for 30 minutes at a temperature of 100 °C. As the physical and chemical investigations showed, the formation of nanoparticles with the sizes from 10 to 50 nm occurred when the samples were calcinated in a thermostat at a temperature of 400–450 °C for 1 hour, this was accompanied with (using concentrations of the active component ≥ 1%) a near bluish glow.

Figure 1 shows the sequence of stages in the synthesis of fiberglass catalyst samples.

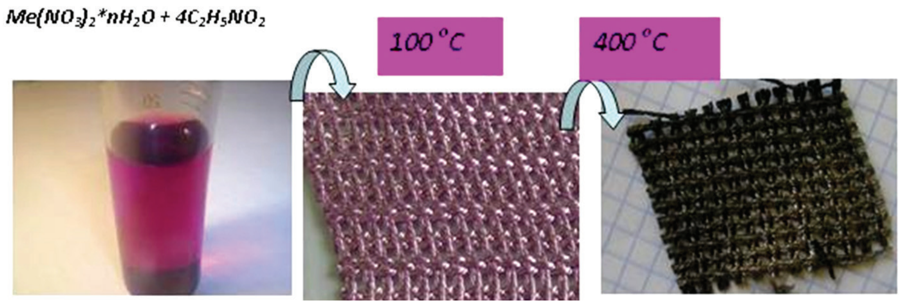

Figure 1. Sequence of stages of synthesis of samples of fiberglass catalysts.

Figure 2a below shows a three-dimensional image of individual particles of catalyst 1.0-KS-0/100, which were separated from the substrate using a supersonic disperser. TEM image of catalyst 0.8-KT-60/40 (Fig. 2b) shows that cobalt and nickel particles with sizes of about 5–20 nm are present on the glass cloth surface.

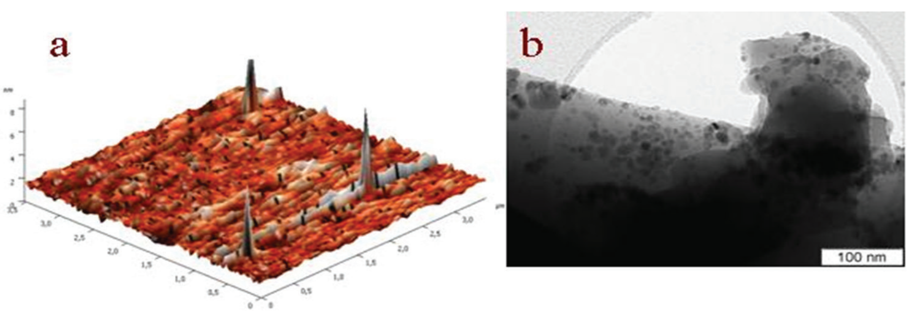

Figure 2. Particles of synthesized silicon after chemical treatment in hydrochloric acid.

15. Preparation of mesoporous nanofibers of polymethyl methacrylate (PMMA) with various additives by electrospinning

The second series of experiments was carried out to produce fibers adding a saturated solution of cobalt chloride in ethanol to the initial solution of PMMA. As can be seen from the photos of the obtained samples (Fig. 3), the diameter of fibers ranges from 600 nm to 4 μm, in addition, the fibers have a mesoporous structure with pore sizes within the range of 150–500 nm. It can be noted that these fibers have inside cavities with a fairly strict periodicity along the complete length of the fiber. Hence, with an appropriate choice of the composition of the two-component mixture, it is possible to obtain porous fibers with different inclusions. In this case, the pore measure can change over a wide range.

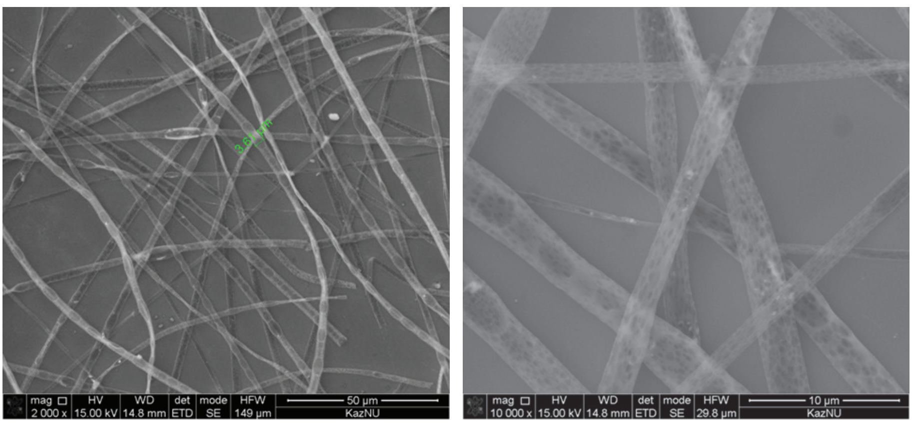

Figure 3. Atomic force microscopy (AFM) photographs of porous polymethyl methacrylate fibers.

Thus, the electrospinning process provides ample opportunities for obtaining modified fibers and fibers with a complex structure. In addition, it is possible to combine the processes of electrospinning and electrospraying, which has its practical application in the manufacture of filters, catalysts and nanoparticles with the desired properties.

It can be argued that the synthesis of fullerenes and carbon nanotubes in a flame is an alternative technology to the existing methods of synthesis in an electric arc from graphite. Also, SH synthesis of nanopowders of metal oxides and catalysts is an alternative to the common technology of producing inorganic substances and materials. Their characteristic features are: the use of chemical energy of combustion processes, instead of electric energy; simplicity of equipment, due to the absence of external sources of power; and high rate of the process.

Current research topics at the Institute of Combustion Problems

In addition, a number of other nanotechnologies that are in request today are being developed at the Institute of Combustion: technology for the production of heat-insulating materials and items (plates, sections, semi-cylinders) for the needs of the country's heat power industry, technology for neutralization of contaminated soils, technology for creating nanostructured coatings of electrodes for plasma-chemical reactors, etc. The research topics currently developed at the institute are the following:

1. Establishing of the physical and chemical foundations of electromagnetic technology for smelting natural basalts and energy slags and obtaining fiber from the melt.
2. Establishing of the scientific foundations of plasma technology for obtaining synthesis gas from organic matter and valuable components from the mineral mass of coal.
3. Establishing of the scientific and technical foundations of plasma activation of combustion of solid fuels in pulverized coal furnaces of power and industrial boilers.
4. Study of the physicochemical laws of the extraction of metals during out-of-furnace centrifugal combustion under centrifugal forces.
5. Synergism of inorganic salts in the combustion and extinguishing processes.
6. Establishing of the scientific foundations of the theory of flame front bifurcation and development of a new criterion in the production of rocket fuel for space energy of the Republic of Kazakhstan.
7. Development of effective fire-retardant foaming coatings by forming a protective carbonized layer with high thermal-oxidative and erosion resistance.
8. Application of damp mechanical actuation for the opening of refractory ores and extraction of valuable metals.
9. Development of the theory and method for modeling turbulent combustion

of hydrocarbons, taking into account the intermittency effect.

10. Achieving control over the synthesis of fullerenes during the combined combustion of hydrocarbon fuels.
11. Development of the scientific and technological foundation for the synthesis of powder systems with a multilayer structure of particles and nanostructured SHS-composites based on them.
12. Investigation of the processes of interaction of manganese ores with aluminum alloys for the development of technological bases for obtaining alloying materials.
13. Synthesis of fullerenes and carbon nanotubes in a vacuum arc using natural gas.
14. Study of the electronic properties of nanoscale structures of carbon, silicon and silica by calculation methods of quantum chemistry.
15. Investigation of the structure formation of concretes modified by sol-gel processes with the participation of polymers and silica.
16. Development of scientific foundations for production of silicon under the conditions of solid-phase combustion.
17. Study of the mechanisms of nucleation and growth of carbon nanotubes and nano-dispersed particles of metals and their oxides in a diffusion flame. Development and production technologies.
18. Study of SH-synthesis of composite carbide-containing materials.
19. Development of methods for increasing the floatation activity of mineral oxidation.
20. Development and realization of the technology for production of bitumen and asphalt concrete mixtures from oil-bituminous rocks of the Republic of Kazakhstan.
21. Development and realization of technologies for production of nanomaterials for the creation of two-layer electrochemical capacitors of high capacity.
22. Firing ceramic materials with improved thermophysical characteristics.

Conclusion

Mansurov's scientific school of chemical physics and nanotechnology in Kazakhstan brings together a large group of highly qualified specialists, representing the scientific trend of "invisible college" and organizationally functioning within the framework of the research of the Institute of Combustion Problems (Mansurov, 2006, p. 396).

Here it should be noted that Kazakhstan is the only republic in the post-Soviet space where, in addition to the experiment to build a society of universal justice (the project of the USSR), a nuclear explosion was carried out in Semipalatinsk, and the first flight into space was carried out from Baikonur. These phenomena are associated with the latest achievements of science and technology. Probably, it is no coincidence that the country became the second homeland of many repressed peoples of the former USSR. Apparently, there is a certain pattern in the fact that a descendant of the great Heraclitus created the Institution of Combustion on our long-suffering land. This greatest ancient Greek thinker believed that fire is a source from which everything happens, that fire is the root cause of everything. His substantial dialectics—the doctrine of universal development and change—can be viewed as a general metaphor of the evolution of science.

There is no doubt that a student, worthy of his teacher, founder of his own scientific school within the walls of the Institute of Combustion, has led it through the storms of the transitional period after the collapse of the USSR, without losing its scientific potential and in some aspects even strengthening it, while preserving jobs and expanding international cooperation not only with the neighboring countries but also with the developed countries in the West and East. This was facilitated by Mansurov's one-year internship at the University of London, England in 1981, in the course of which he perfectly mastered the English language but also got the opportunity in the Iron Curtain era to compare the education and science systems that later helped him successfully integrate his scientific school into the educational and scientific space of the world. His amazing ability to communicate with people of different classes, ethnic groups and religions was apparently inherited from his father, a veteran of war and labor. By his personal example Mansurov showed how to build relationships by trying to do good for most of the people he worked with and strictly delivering on promises.

Without a doubt, the formation of Mansurov's scientific school was impacted by his administrative career, as he went from an intern-researcher at the Department of Physical Chemistry to the primary vice-rector of the biggest university in the Republic of Kazakhstan. For more than 15 years he was the vice-rector for science and the primary vice-rector. He cooperated in the establishing of six research institutes, opening of a scientific-technological park, publishing the journal *Bulletins* in 16 series, including one in English, and was involved in a number of projects related to publishing houses, culture and education (Sadykova, 2006, pp. 4–5).

Thus, it can be concluded that the Professor Z. A. Mansurov's scientific school of chemical physics and nanotechnology in Kazakhstan is a team of highly qualified specialists working organizationally within the framework of the research work of the Institute of Combustion Problems. In terms of the scope of research in the theory of combustion processes, the scientific school focuses on fundamental and applied research. The goals and objectives are determined by the methodology of the founder of the school aimed at developing fundamentally new approaches to studying the flame front, searching for economically and environmentally promising sources of raw materials and new nanotechnologies.

The Kazakhstani scientific school of chemical material science is characterized by multi-level contacts between its members and generations of analysts, and in terms of the degree and levels of cooperation, a clear structure can be seen inside the research organization, the chemical department of the university, research centers and institutions of Kazakhstan, as well as several institutions of higher education abroad. Therefore, we can speak about the national and international level of the scientific school, laid down in the Soviet period by researchers of international acclaim, based on the common methodology of the approach to combustion processes—self-propagating high-temperature synthesis (SHS). These new significant scientific results are a noteworthy contribution of the Kazakhstani scientific school of chemical physics and nanotechnologies to the formation of competitive science and economy in Kazakhstan.

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