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The History of the Academic Institute ISMAN

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Abstract

The article is devoted to the history of the recognized leader in the field of basic and applied research into the processes of combustion and explosion – the Institute of Structural Macrokinetics and Materials Science (Russian acronym ISMAN). The Institute is unique due to its mission – the development of a new scientific and technical trend – self-propagating high-temperature synthesis (SHS). SHS is based on the discovery of a new phenomenon "solid-flame combustion" made by Russian scientists. The developments of principally new techniques for manufacturing materials and products based on this phenomenon have become an important achievement of the Russian science. The materials presented in the paper will give the reader a clear insight into the main fundamental and applied studies of the Institute, the results of its cooperation with domestic universities in the field of education and science.

Keywords

Self-propagating high-temperature synthesis; solid-flame combustion.

Introduction

The history of the Institute of Structural Macrokinetics and Materials Science (**ISMAN**) begins from the time when A.G. Merzhanov, an outstanding representative of Nobel prize laureate academician N.N. Semenov's school, formed and led a group of scientists in the Branch of the Institute of Chemical Physics in Chernogolovka. The group included the V.G. Abramov, V.V. Barzykin, E.I. Maksimov and A.K. Filonenko. They should be referred to the first wave of researchers of the laboratory of ignition and combustion-to-detonation transition established in 1959. I.P. Borovinskaya and B.I. Chaikin should be also ranked among this group (they came to work at the Institute of Chemical Physics Branch a bit later). The activity of this group was of fundamental importance on the long way of laboratory transformation into the Institute of Structural Macrokinetics and Materials Science. These scientists contributed not only to the creation of experimental and theoretical basis to study the laws of ignition, combustion and explosion processes, but also, which is more important, a systematic approach and methodology for studying these processes. That appeared to be, in our opinion, the basis and favorable environment for a further discovery of a new phenomenon "solid-flame combustion" made by A.G. Merzhanov, I.P. Borovinskaya, V.M. Shkiro (discovery number 287 "The phenomenon of wave localization of self-inhibiting solid-phase reactions", 1967), in which starting reactants, intermediate products, and final products are present in their solid state throughout the entire process (Fig. 1). Solid-flame combustion subsequently was recognized as a major scientific discovery and major achievement of Russian science [1].

Fig. 1. A.G. Merzhanov, I.P. Borovinskaya, V.M. Shkiro

This allowed the authors not only to discover and study the entire classes of previously unknown

phenomena, reactions and compounds, but also to create an essentially new, original and powerful method for industrial production, open new directions in theoretical and applied materials science.

Alexander G. Merzhanov far-sightedly assessed the scope and prospects of this discovery as the basis for a new economical technology of producing inorganic compounds and composite materials, called self-propagating high-temperature synthesis (**SHS**). Since that time the dramatic, complex, having sharp turns, history of the scientific direction of SHS started. It seemed that the advantages of the new method of synthesis, based on the use of combustion as compared to conventional furnace technologies are evident: the fusion process itself takes place within fractions of seconds (instead of hours), herewith the technology is considerably simplified, and there is no need for complex and expensive equipment. All this makes it tempting to use combustion for the synthesis of many refractory compounds and materials, such as ceramics, cermets, hard alloys, coatings, etc. However, the idea of SHS had to share the fate of all the fundamental discoveries and go through the steps: "this cannot be", "there is something in this", and then "it had long been known". Some experts, accustomed to traditional technologies, gave a hostile reception to A.G. Merzhanov's new ideas, met them with alienation and distrust. It was an unwelcome intrusion into their areas of interest. Such is the force of habit: constantly striving for the new, people hardly decline the old.

Now it is almost forgotten how many wounds, hard knocks and shocks the founders of SHS, A.G. Merzhanov and his irreplaceable assistant, associate and spouse I.P. Borovinskaya, experienced. Those scientific and pseudo-scientific battles required from them a lot of effort, the ability to endure and keep hitting. They brought out clearly that responsibility for dealing is more important than their personal well-being. A.G. Merzhanov proved to be a talented organizer, able to clearly explain the results of scientists' work and demonstrate their benefits to producers. It was then when he formulated the basic objectives and approaches of the fundamental ideas of the theory of SHS, which he called structural macrokinetics. He managed to turn the tide. As a result of the solution of control problems of the process of structure formation of SHS-products, the technological capabilities of SHS were identified, the manufacturing and material science base of this technology was created [2].

Organization of the Institute

Till 1971 the development of the theory of SHS-processes and the study of chemistry and physico-mechanical properties of SHS-products were conducted on a full scale. At that time the mechanisms of combustion; kinetics, thermodynamics, theoretical models of solid combustion; composition, structure and properties of the end-products were investigated. In 1971, the laboratory of ignition and combustion-to-detonation transition was transformed into macrokinetics and gas dynamics department. The department continued to study physico-chemical SHS-processes and proceeded to engineering works. Experimental and theoretical work in the field of SHS began to develop rapidly in several areas of science and technology under the supervision of the people who shared A.G. Merzhanov's ideas:

– Forced SHS, SHS-gasostatic treatment – I.P. Borovinskaya;
– Power SHS-compaction – V.I. Ratnikov;
– SHS-metallurgy – V.I. Yukhvid;
– SHS-extrusion – A.M. Stolin;
– SHS-welding – A.S. Steinberg.

We can say that SHS has moved from the area of basic research to the area of practical application as a simple and cheap technique of obtaining important for production compounds and materials. Thus, in 1972 in Chernogolovka the first pilot plant which produced 10-20 t per year was set up. Three years later, together with the Institute of Materials Science Problems, Ukraine Academy of Sciences highly-efficient pastes based on SHS-powder of titanium carbide were created and tested at 300 enterprises. In the late 70s commercial production of SHS-products started at Kirovakan plant of high-temperature heating devices.

From 1979 to 1983 the nationwide system for the study, application and development of the SHS-technology was formed. During this period, the State Committee of Science and Technology established the Scientific Board of "Theory and Practice of SHS-processes", which held thematic sessions on specific promising areas of SHS.

It was at that time when the President of the Academy of Sciences G. Marchuk and the Chairman of the Council of Ministers N. Ryzhkov carried out a statewide experiment on creating interbranch scientific and technical complexes (**ISTC**) which included the interrelated institutes, design bureaus and plants. The mission of 16 ISTCs was to create an experimental-industrial technology.

One of the ISTCs called "Thermosynthesis" was aimed at the development and application of "solid-flame combustion" research. In 1979 a decree of the USSR Council of Ministers on the design and construction of the SHS-complex in Chernogolovka was issued. In 1987 by decree No.186 of the Presidium of the USSR Academy of Sciences of April 21, 1987 it was decided:

– to create the Institute of Structural Macrokinetics of the USSR Academy of Sciences (ISMAN) with design-engineering services, pilot production, a pilot plant, an educational center for training specialists at the Noginsk Research Center of the USSR Academy

of Sciences (Chernogolovka, Moscow region) based on the Department of Macrokinetics and gas dynamics of the Institute of Chemical Physics of the USSR Academy of Sciences, a complex of buildings and SHS facilities built in accordance with the decree No. 81-2 of January 23, 1979 of the Council of Ministers;

– to make the Institute of Structural Macrokinetics of the USSR Academy of Sciences responsible for the implementation of the functions of the parent organization ISTC "Thermosynthesis" of the USSR Academy of Sciences and the Ministry of non-ferrous metallurgy of the USSR (Mintsvetmet);

– to include the Institute of Structural Macrokinetics of the USSR Academy of Sciences in the Department of General and Technical Chemistry of the USSR Academy of Sciences.

Thus, the world's first institution was created, whose activities were devoted to the problems of the theory and practice of SHS.

The institution was rightly headed by its founder – an outstanding scientist, academician A.G. Merzhanov. When the Institute was organized a question was raised what structure it should refer to. Mintsvetmet of the USSR laid claim to it. However, A.G. Merzhanov believed that the Institute should be part of the Academy of Sciences. But the heads of the government did not give up, and it became clear that the simple reasons are not enough to solve this question. The way out was found. A.G. Merzhanov proposed to transfer the entire complex "Thermosynthesis" under the guidance of Mintsvetmet, and reserve the Institute within the framework of the Academy of Sciences. Since the entire complex "Thermosynthesis" was a larger institution, all the attention was focused on it, and the Institute was transferred to the Academy. As a joke this situation became known as A.G Merzhanov's gift to the Academy of Sciences. The appearance of the Institute and the ISTC "Thermosynthesis" was an important sign of the manifestation and development of innovations.

Life itself made it necessary to create a unique new institute, whose scientists came to define the global level of development of research in the field of SHS. In 1988 M. Gorbachev, General Secretary of the Communist Party of the Soviet Union, said: "We expect a great deal from the introduction of technology of obtaining materials by SHS-technique, which has no analogues in the world".

Expansion of research in the field of SHS and increase in the potential of these studies largely determined the establishment of various research centers in our country. These centers arose in Moscow, Samara, Tomsk, Yerevan, Almaty and other cities of the Soviet Union.

There appeared production sites in Kirovakan, Baku and Yerevan, manufacturing products based on SHS-technology. The number of scientists, engineers and manufacturers working in this area and having received new training sharply increased.

The Institute of Today

The traditions of the Institute have been preserved and developed at different times by all the directors of the Institute (Fig. 2).

At present the Institute is a recognized leader in the field of basic and applied research into the processes of combustion and explosion, including SHS and the application of these processes for developing and producing new materials. The fundamental directions are actually those trends that are developed by the academic institute today. In ISMAN, for example, it is structural macrokinetics (**SMK**) which deals with direct and inverse non-linear relations between the rates of chemical reactions of phase and structural transformations and heat and mass transfer. The researchers of the Institute are working to develop scientific foundations of solid-flame combustion phenomenon, which has received theoretical and experimental diagnostic justification. Not every institute has a scientific discovery underlying its activities and has its own face.

A.G. Merzhanov
1987 – 2005

Yu.A. Gordopolov
2005 – 2012

M.I. Alymov
2012 – till present

Fig. 2. The directors of the Institute

The main trends of fundamental and applied research of the Institute are:

– general and structural macrokinetics of the processes of combustion and explosion;

– self-propagating high-temperature synthesis;

– synthesis and modification of materials under high dynamic pressures;

– control of the processes of combustion and explosion, chemical power engineering;

– scientific bases of new highly effective technologies for creating structural, functional and tool materials and coatings; Materials Science.

The fundamental and applied studies of the Institute are carried out within the framework of the priority areas of science, technology and engineering in the Russian Federation (approved by Presidential Decree No.899 of July 7, 2011):

– security and counteraction against terrorism;

– industry of nanosystems and materials;

– perspective types of weapon, military and special equipment;

– rational nature management

and correspond to the list of critical technologies of the Russian Federation (approved by Presidential Decree No.899 of July 7, 2011).

Integration with Universities

Integration of academic science and higher professional education has always been a question of great importance for Russian Academy of Sciences and the Institute. In ISMAN in due time there were established 4 basic departments: a branch of the "SHS-processes" department at the department of high-temperature processes, materials, and diamonds at physico-chemical faculty of Moscow Institute of Steel and Alloys (Russian acronym MISIS); department of macroscopic kinetics of Moscow Region branch of Moscow State University; department "Materials Science and SHS-technology" at Samara State Technical University (Samara); department "Physics and Technology of Composite Materials" at Altai State Technical University (Barnaul). In the structure of the Institute there emerged "Scientific and Education Center" (SEC ISMAN). A special building was constructed for SEC ISMAN to function with a comfortable hostel for 30 people (double rooms with all conveniences), a lecture hall and a gym, a computer classroom, a dining room and utility rooms.

In practice profile SECs which are created jointly by some university and academic institute on a particular scientific trend are becoming widespread. This form of integration of science and education suggests that the interaction between the university and academic institute takes place through the development of collaborative research with educational functions being fully performed by the university and research base being used by both organizations. This allows to pull up research work at the university to the level of academic research and get targeted funding from the Ministry of Education and Science.

Now two specialized centers in the Institute function on this basis:

– Scientific and Education Center SHS (SEC SHS) of the National Research Technological University "Moscow Institute of Steel and Alloys" and ISMAN. It was established on the initiative of academician A.G. Merzhanov and Professor N.N. Havsky by the joint order-decree of the USSR State Education and Presidium of the USSR Academy of Sciences No.744/119 of 21.09.1989 as the country's first joint research and education complex, combining efforts and resources of the higher educational institution and the Academy of Sciences to conduct fundamental research, develop and apply achievements at industrial enterprises, train and retrain specialists in various aspects of scientific problems.

– Profiled SEC TambSTU-ISMAN "Solid-state technology". It was founded in 2005 on the basis of Tambov State Technical University and ISMAN. Solid-phase technology includes obtaining items when initial components and products are solid. Examples of such technologies are SHS-technology, powder metallurgy, solid-phase extrusion, pressing, solid polymers forming.

The students of MISIS (Moscow), RCTU (Moscow), Moscow State University (Moscow), Moscow Engineering Physics Institute (MEPhI), Samara State Technical University (Samara), Kazan STU (Kazan), PTU (Penza), TSTU (Tambov), Altai State Technical University (Barnaul), Syktyvkar State University (Syktyvkar), Ugra State University (Khanty-Mansiysk), Yerevan State University (Yerevan), USATU (Ufa), State University of Mordovia (Saransk), Samara State Academy of Railway Transport (Samara) have been trained at ISMAN.

With a number of these universities there were established long-term relations on the basis of bilateral agreements (Penza State University, Tambov State Technical University, Kazan State Technical University, National Research Technological University "MISIS", Moscow State University, Samara State Technical University, Samara State Academy of Railway Transport, Ufa State Aviation Technical University, Altai State Technical University, Baltic Federal University.

It should be noted that ISMAN works not only with Russian universities. At the Institute there have been trained young scientists from Armenia (Institute of Chemical Physics, National Academy of Sciences), India (Institute of Metallurgy, Dzhamshirpur), France (Universities of Poitiers, Dijon, Paris), China (Beijing University of Technology), Italy (Turin Polytechnic Institute), USA (University of Notre-Dame), Kazakhstan (al-Farabi Kazakh National University).

Organization of Symposia and Conferences

Every two years since 1991 the worldwide achievements in the field of SHS have been reported at the International Symposium on Self-Propagating High-Temperature Synthesis (International Symposium on SHS). The symposium was held in different countries: (Alma-Ata, Kazakhstan, 1991; Honolulu, USA, 1993; Wuhan, China, 1995; Toledo, Spain, 1997; Moscow, Russia, 1999; Haifa, Israel, 2002; Poland, 2003; Italy, 2005; France, 2007; Armenia, 2009; Greece, 2011; Texas, USA, 2013; Turkey, 2015. These symposia are organized by research teams in each of these countries most actively working in the field, with Russian participants playing a key role in the preparation of the scientific program and carrying out the Symposium.

The "International Journal of Self-Propagating High-Temperature Synthesis" with the editorial board in ISMAN is regularly published.

Every year since 2003 All-Russian (with international participation) youth school-conferences on structural macrokinetics are held at ISMAN (Chernogolovka, Russia). At the School much attention is paid to the up-to-date problems of materials science, thermodynamics, chemical kinetics, metallurgy and medicine. The School is annually attended by more than 120 representatives of scientific institutions of Moscow, Moscow region towns and cities of Samara, Ufa, Barnaul, Tambov, Novosibirsk, etc.

Many of the studies are conducted in collaboration with foreign organizations. Representatives of other countries such as France, the USA, Kazakhstan, Armenia, Belarus, etc. take part. The peculiarity of the School is the participation in its work with oral presentations of students engaged in research activities at the Center of Additional Education "Impulse" in Chernogolovka.

Problems and achievements in the field of combustion synthesis of materials are discussed at many leading conferences on materials science, chemistry and combustion, including the global materials science forum CIMTEC (Special Symposium on SHS within the Forum). Bilateral scientific seminars in this field are also conducted (Russian-French, Russian-Chinese, Russian-Japanese, Russian-Indian).

SHS Overseas

It should be noted that the prospects and effectiveness of SHS-technology was highly evaluated overseas. In the USA and Japan this problem was actively developed in the 80s. American and Japanese scientists developed functionally gradient materials, manufactured large-size pipes using centrifugal SHS-casting. A little later, Chinese scientists took an interest in SHS and have made impressive progress in recent years. Active research on SHS is also done in India, Poland, Korea, Spain, France, Yugoslavia and other countries. Virtually all major foreign publications recognize the priority of Russian scientists. Here are some statements of foreign scientists in foreign press:

"The Soviets have demonstrated that SHS-method is a cost-effective technique of producing various ceramic materials. Some materials exhibit exceptional properties directly resulted from the uniqueness of SHS-process. SHS- technology of these materials has demonstrated the potential for producing refractory compounds on an industrial scale, and in the case of titanium carbide and molybdenum disilicide it has replaced the conventional production process, which requires a lot of energy expenditure... No parallel technology exists in the US" (Crider, 1983).

"The current interest in SHS is largely due to intensive research in this field in the Soviet Union, for example, the production of titanium compounds" (Rice, 1986).

The pioneering and leading role of modern national SHS-school is recognized. There are only a few attempts of American Scientists to change the terms "SHS" and "structural macrokinetics", the honor of introduction of which rightfully belongs to A.G. Merzhanov. The creation of a fundamentally new technology within this direction, the development of its theoretical foundations are the greatest achievements of Russian science and evoke a sense of pride among the staff of the Institute.

ISMAN uniqueness consists in its mission – the creation of new processes and technology of production of materials and goods, and not only the improvement of consumer properties of final products. In effect, these are different tasks. The second problem is technical in its nature, and the first is technological. A.G. Merzhanov is the founder of SHS-technology, and almost in all major publications of foreign scientists the leading role of ISMAN scientists in this new field of science and technology is recognized. Despite the large scale of world research in this area, the results of Russian scientists occupy a worthy place and in a number of directions Russian scientists maintain global scientific leadership.

Today, despite the difficulties, the Institute continues to work at a high world level in various fields of physics and chemistry of combustion processes, material science, structural macrokinetics, technology of chemical synthesis of inorganic materials.

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