Production of New Materials Using Explosion Energy and Self-Propagating High-Temperature Synthesis

From 14 to 18 May 2018 St. Petersburg hosted the 14th International Symposium on the Explosive Production of New Materials: Science, Technology, Business and Innovation (EPNM-2018).

The symposium was organized by the A.G. Merzhanov Institute of Science Institute of Structural Macrokinetics and Materials Science of Russian Academy of Sciences (ISMAN, Chernogolovka) and Energometall AO (St. Petersburg) with the support of the Russian Foundation for Basic Research (Project 18-08-20027) and the Division of Chemistry and Materials Science of the Russian Academy of Sciences.

More than 120 specialists from Russia, Portugal, Poland, Germany, France, Netherlands, Ukraine, Czech Republic, Slovakia, Armenia, Estonia, USA, Brazil, China and Japan took part in the EPNM-2018.

Based on the results of the materials presented, a collection of materials was prepared for the International Symposium "EPNM-2018" – Proceedings of the XIV International Symposium on Explosive Production of New Materials: Science, Technology, Business, and Innovations [Edited by M. I. Alymov, O. A. Golosova]. Moscow: TORUS PRESS, 2018. 362 p. ISBN 978-5-94588-230-0. At the Symposium, 84 reports were presented, including 46 oral presentations and 38 poster presentations.

At the opening ceremony, the co-chairmen of the Organizing Committee, the ISMAN Director, Corresponding Member of the Russian Academy of Sciences M.I. Alymov addressed the attendees of the Symposium with a welcome speech. Prof. J. Banker (USA), Professor Ricardo Mendes (Portugal), Dr. Zygmunt Szulc (Poland), and others also spoke at the opening ceremony.

The plenary speech of M.I. Alymov covered the results of the research conducted at the institute on explosion welding, self-propagating high-temperature synthesis and electrothermal explosion. The President of Clad Metal Consulting, J. Banker presented the analysis of the formation and development of metalworking by the explosion in the world. He concluded explosive punching failed to compete with other metal-shaping technologies and ceased to exist, while explosion welding firmly holds its niche in commercial production with a global annual volume of about 1 billion US dollars. According to J. Banker, it is necessary to constantly search for new areas of application of this technology. V.S. Vakin presented a detailed report of the 10th practice of explosion welding work at Energometall AO, gave examples of successful cooperation in the manufacture of commercial products, in particular, the company manufactured bimetal for the International Experimental Fusion Reactor under construction at the Cadarache Research Center in the south of France (ITER project).

All reports on recent work in the field of processing and synthesis of materials with the use of explosion and high-temperature synthesis, presented at the symposium, were interesting and informative. For example, A.A. Shterzer (co-authors A.A. Deribas, E.E. Zubkov) described another "explosion" technology – explosive hardening, which is successfully used in the commercial production of railroad switch frogs. The representative of the Research Center "Kurchatov Institute" – CNII KM "Prometey" – I.A. Schastlivaya presented in detail the results of many years of research into the mechanism and growth of defects in bimetallic materials (steel/titanium), depending on the ongoing technological operations and types of loading.

A detailed plenary report on the latest achievements of fundamental and applied science in the field of superplasticity and intensive plastic deformation of high-temperature metallic materials for the production of complex profile products used in the aerospace and aviation industries was made by Corresponding Member of the Russian Academy of Sciences, Director of the Institute of Metal Superplasticity Problems, RAS R. R. Mulyukov.

All reports made by the Symposium speakers are of interest to researchers, engineers and businessmen working in the field of producing new materials by high-energy techniques. It should be noted that in recent years active research on aluminum-steel explosive welding using emulsion explosives and ANFO (mixture of ammonium nitrate with diesel fuel) has been conducted at the University of Coimbra in Portugal (R. Mendes, I. Galvao, G. Carvalho and other). As for the ANFO, the experiments important for practical applications conducted by V. Petr from the Colorado School of Mines (USA) found a significant effect of the density of ammonium nitrate particles on the detonation rate of this explosive. Serious progress has been achieved by the scientists of the Beijing Institute of Technology (Institute of Technology,

Beiling, China) under the leadership of Professor P. Chen. For example, the report presented by Q. Zhou describes interesting results on the synthesis of multi-layer graphene (a few-layer grapheme) by shock wave method, and H. Yin described the preparation of iron nanoparticles in a carbon shell by blasting an explosive mixture with iron tristearate in evacuated vacuum chamber. The studies on the shock wave loading of tungsten carbide in the megabar range conducted by T. Schlotauer from the Technical University of the Freiberg University of Engineering showed a WC → W_2C + diamond transition. The reports made by L. Kecskes from Matsys Inc. Sterling (USA) about the studies carried out jointly with researchers from Georgia (A.B. Peikrishvili, E.Sh. Chagelishvili, G.F. Tavadze, B.A. Godibadze and others) were informative. To produce compacts from high-strength materials, they use the effective method of Hot-Explosive Consolidation (HEC). In Ta–Al, Nb–Al and V–Al powder mixtures, due to high-temperature heating above the start-up temperature of self-propagating high-temperature synthesis (≥ 940 °C for Ta–Al), blasting occurs in the liquid-phase state of the SHS product. The HEC method also produced low-porosity compacts from nanosized W–Ag, W–Cu, W–Ta powder mixtures.

A number of reports were devoted to the study of the high-speed collision of materials, the study of the bond zone in bimetals and the study of the synthesis process using the most modern methods, instruments and equipment. The Japanese researcher A. Mori from Sojo University presented optical images of shaped jets that occur under oblique collision of plates from dissimilar materials. It is characteristic that when copper collides with the AZ31 magnesium alloy, the alloy particles, of which the jet consists, ignite when interacting with air. H. Paul, from the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences studied the zone of connection of various metal pairs (steel / titanium (Gr. 5), steel/ zirconium alloy Zr700, titanium (Gr. 1) / copper, etc.) with the help of transmission electron microscopy and scanning electron microscopy (TEM and SEM) and concluded that there is always a very thin layer of melt in the contact zone. K. Saksl from the Institute of Materials Science of the Slovak Academy of Sciences reported on a new method for the diagnosis of residual stresses in bimetal – a two-dimensional X-ray diffraction method with a synchrotron source and with a focal spot size of 20 μm. With the use of the same synchrotron radiation, in the time-lapse photography mode with a picoseconds exposure, K. Ten from Lavrentyev Institute of Hydrodynamics SB RAS and his colleagues from other institutes of the SB RAS managed to fix the formation and growth of nanodiamonds in a detonation wave.

It should be noted that, in comparison with previous events, the symposium theme expanded and the interdisciplinary nature of the presented studies was very impressive, which was noted at the closing ceremony of the symposium by the speakers. The program of special interest sessions, which was devoted to the results of research in the field of self-propagating high-temperature synthesis, included reports on the theory and modeling of combustion processes, the synthesis of functional and structural materials, protective coatings, layered composite materials, powder materials, as well as the study of new hybrid processes combining SHS and subsequent processing of the produced materials.

Professor A.M. Stolin (ISMAN) presented a report describing the new technological approach and the latest results obtained using the method of free SHS-pressing. The first samples of ceramic plates with dimensions over 100 mm, made from a titanium diboride-based material were demonstrated. S.V. Karpov (Tambov State Technical University) spoke about modern approaches to mathematical modeling of complex non-stationary heat transfer processes in the free compression of hot SHS products.

Several presentations were devoted to the study of the laws of high-temperature synthesis of the so-called ultra-high temperature materials. Professor V.I. Yukhvid (ISMAN) showed wide possibilities of using the SHS-metallurgy method for producing materials based on molybdenum silicide, used as a basis for products capable of operating in oxidizing environment at temperatures higher than 2000 °C. A.Yu. Potanin, the young researcher from MISiS presented the results of the studies on high-temperature synthesis of ultra-high-temperature materials based on ZrB_2, doped with SiC, $MoSi_2$, and HfB_2 in demand for the manufacture of critical products for hypersonic aircraft. Professor V.A. Sherbakov (ISMAN) in his report spoke about important, practically significant results on obtaining dense ultra-high-temperature ceramics based on complex Ta_4ZrC_5–CrB and Ta_4HfC_5–CrB systems.

Traditionally, a significant amount of studies was devoted to SHS materials based on intermetallic compounds. Professor A.G. Knyazeva (Tomsk State University) presented a detailed report on the results of mathematical modeling of high-temperature interaction processes in the synthesis of materials based on the Ti–Al system. A.E. Sychev (ISMAN) made an interesting report on the synthesis of nickel aluminide

with a modifying carbon additive. It was found that platelet (graphene-like) carbon emissions along grain boundaries of the intermetallic compound promote an increase in ductility while maintaining strength. The young scientist E.I. Patsera (the MISiS University) presented the results on the synthesis of microgranules from promising intermetallic CompoNiAl-M_5 alloy for the formation of products of complex shape by using additive 3D-technologies. One can note an interesting report made by the young researcher A.V. Sobachkina (Altai State Technical University), who showed that the gamma-ray treatment of a mechanically activated mixture of Ti + Al powders increases the homogeneity of the TiAl product made by the SHS method and its stability under long-term high-temperature annealing conditions.

At the symposium, a number of reports were presented on the consolidation of porous materials using spark plasma sintering (**SPS**), including in combination with other methods of action on the substance. Thus, the researchers from Armenia and Estonia – S. Aydinyan and T. Minasyan – made interesting reports on the sintering of ZrC+TiC+$MoSi_2$ ceramics and consolidation of Mo+Cu nanopowder by the SPS. Professor E.G. Grigoriev (National Research Nuclear University "MEPhI") presented a comprehensive report on consolidation using high-voltage electric pulses for the production of thin rings of soft magnetic alloy 49K2FA.

V.N. Sanin (ISMAN) presented a report on solving environmental problems through the disposal of man-made waste generated during high-temperature metalworking (rolling, punching, etc.). The possibility of commercial realization of the SHS method for a wide range of cast, complex-alloyed ferroalloys of various practical applications was shown.

At the EPNM-2018 symposium, a competition for the best study of young researchers was held; the International Advisory Committee selected the winners. Three specialists, a researcher from Armenia, Sofiya Aydinyan, (Tallinn Technical University), Sergey Karpov (Tambov State Technical University) and Amadeusz Kurek (Explomet, Poland) won the 3rd prize. The 2nd prize was awarded to Gustavo Carvalho (University of Coimbra, Portugal) and Sheng Zemin (Beijing Institute of Technology, PRC). The 1st prize was awarded to the young researcher Ivan Batayev (Novosibirsk State Technical University). All the winners were awarded memorable souvenir plates with views of St. Petersburg.

Some of the international participants of the Symposium came to Russia for the first time. The organizers provided an exciting social program, with a tour of St. Petersburg, a magnificent city on the Neva. For the participants of EPNM-2018, a boat trip along the Neva with an exit to the Gulf of Finland was organized. The attendees admired the beautiful views of St. Petersburg, took lovely photos and learned

some of the history of St. Petersburg, one of the best cities and the cultural capital of Russia. An excursion to Petergof with a walk along the Upper and Lower Parks, a visit to the grottoes, as well as an excursion to the Grand Palace, which impressed everyone with its splendor, were organized. Peterhof, which is often called the Russian Versailles, proved to be even more exciting than one would expect. After the excursion to Petergof, the participants of the EPNM-2018 attended a master class on matryoshka painting organized in the village of Shuvalovka (the Russian style village). Within an hour more than a hundred people – venerable doctors of science, professors, and young researchers painted their personal matryoshka, with all their diligence and mastery, while listening to the story of the creation of the world-famous Russian doll.

At the closing ceremony, many of the speakers noted the high level of the organization of the event, the warm and friendly atmosphere and the opportunity to communicate, to sum up the results of the studies conducted in the recent period and to outline joint research plans for the future. It was noted that participation of your researchers in such international events is of particular importance. It helps to get talented young researchers involved in promising international scientific research and projects.

Summing up the results of the 14th International Symposium on Explosive Production of New Materials: Science, Technology, Business and Innovation (EPNM-2018), it was emphasized that the methods of processing and synthesizing materials using explosion and high-temperature synthesis are unique inventions of Russian scientists and despite years of research there is still a great scientific and practical potential for future studies aimed at creating new materials with unique properties, which are in great demand for new engineering equipment.

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Please, visit our website to find out more about the program and have a look at the Proceedings of the symposium:

http://www.ism.ac.ru/events/EPNM2018/scientific-program-ru.html