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SHS Ceramics

An introduction to the Focus Issue on SHS Ceramics by

Guest Editor Alexander Rogachev
Merzhanov Institute of Structural Macrokinetica and Materials Science RAS, Chernogolovka, Moscow, Russia

This Focus Issue of the Journal is devoted to ceramic materials produced by Self-propagating High temperature Synthesis (SHS), also known as Combustion Synthesis (CS). After Alexander G. Merzhanov and his co-workers founded SHS in 1967, it diversified into a broad field of knowledge, involving many scientific and technological avenues. Progress in the field of SHS was described in many reviews [1-3] and books [4,5]. A basic idea of this method is integrating of material synthesis and chemical heat generation in a single self-sustained process. Thus, SHS commonly does not require external source of heat for materials production, in contrast to other methods of powder metallurgy, since exothermal chemical reaction releases all required heat *inside* the material. The self-heating of the matter allows creating unique temperature-time regimes of the production: heating rate 10^4-10^6 K/s, temperature of the products up to 3500 K, independent of size/mass of charge, article or workpiece. Ceramic materials, including nitrides, carbides, borides, oxides and others, constitute one of the most important class of the SHS-products. We collected several most representative articles on SHS-ceramic materials in this Issue.

The article by I.P. Borovinskaya, K. Manukyan and A.S. Mukasyan suggests a wide view on the SHS-ceramics, from invention of SHS technology to newest achivements. This is the last paper where professor I.P. Borovinskaya, pioneer of SHS and academician of the World Academy of Ceramics, participated. Basing on the analysis of 50-year period of the SHS development, with focus on recent works, authors came to conclusion that: (1) combustion-based methods allow fabrication of a wide variety of ceramics, including powders, bulk materials, coatings, net shape articles, nanomaterials; and (2) several obstacles of SHS, such as structure uniformity of the produced materials and controllability of SHS process, should to be overcome, before this method can be widely implemented in large-scale production of advanced ceramics. In this regards it is mentioned that investigating the mechanisms of the combustion reactions and structural transformations, which occur during SHS, one might establish effective ways to control the structure of the ceramic materials. Advantages of SHS become evident when this method is applied to materials that are difficult or impossible to produce by traditional methods, rather than production of conventional well-established materials. It is stated that direct fabrication of the net-shape pore-free ceramic articles, as well as synthesis of 1D and 2D nanopowders of refractory compounds, should be among the promising for SHS directions.

Even wider area for SHS-based technologies, that embraces outer space and planets, is considered in the article of Osamu Odawara, Anna Gubarevich, and Hiroyuki Wada. Unlike common combustion, the SHS process can be carried out in oxygen-less atmosphere, vacuum, liquid or gaseous nitrogen, carbon dioxide or deep water; it exists at microgravity of artificial high gravity. The SHS related technologies may find promising applications in very extreme environments, such as colonization of Moon or Mars, or underwater and disaster-area on Earth.

An article of S. Vorotilo, Yu.S. Potanin and E.A. Levashov focuses on carbide- and boride-based ceramics, especially ultra-high refractory ceramics and high-entropy ceramics produced by SHS. Many other types of SHS-ceramics and routes for their production are also considered in this comprehensive review article.

Results of crystal structure study of multicomponent carbides, carbohydrides and carbonitrides, obtained by SHS, are summarized in the article by N.N. Aghajanyan, S.K. Dolukhanyan, O.P. Ter-Galstyan, and N.L. Mnatsakanyan.
Silicon carbide fiber reinforced ceramic materials, based on hafnium diboride, are presented in the article by C. Musa, R. Licheri, R. Orrù, R. Marocco, and G. Cao. It demonstrates that combination of SHS with Spark Plasma Sintering (SPS) is an effective route for production poreless ceramic materials and items. As an example, a nozzle component was obtained for space propulsion application. The SHS+SPS technology was also applied for production of TiB_2-Si composite material with improved properties in the work by L. Liu, S. Aydinyan, T. Minasyan, J. Baronis, and M. Antonov. Nanocomposite material on the base of Ni-W system, produced using thermite-type SHS from oxide precursors and consolidation (SPS), are presented in the article by M. Zakaryan, S. Aydinyan, and S. Kharatyan.
Combination of SHS with shock loading opens up possibilities for production layered composites consisting of non-oxide ceramics (TiB_2, TiN, etc.) and metal or intermetallic, as shown in the work by Ryuichi Tomoshige, Kanako Sonoda, Takumi Nakamura, Takuma Tanaka, Seiichiro Ii, and Yashiro Morizono.
Althought the articles presented in this Special Issue cannot embrace all research topics and technological solutions in the field of SHS, they lead us to conclusion that deep understanding of phase/structure formation mechanisms, and integration of SHS with various methods of materials consolidation (SPS, hot pressing, shock loading, etc.) are principal requirements for further development of this technology.

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