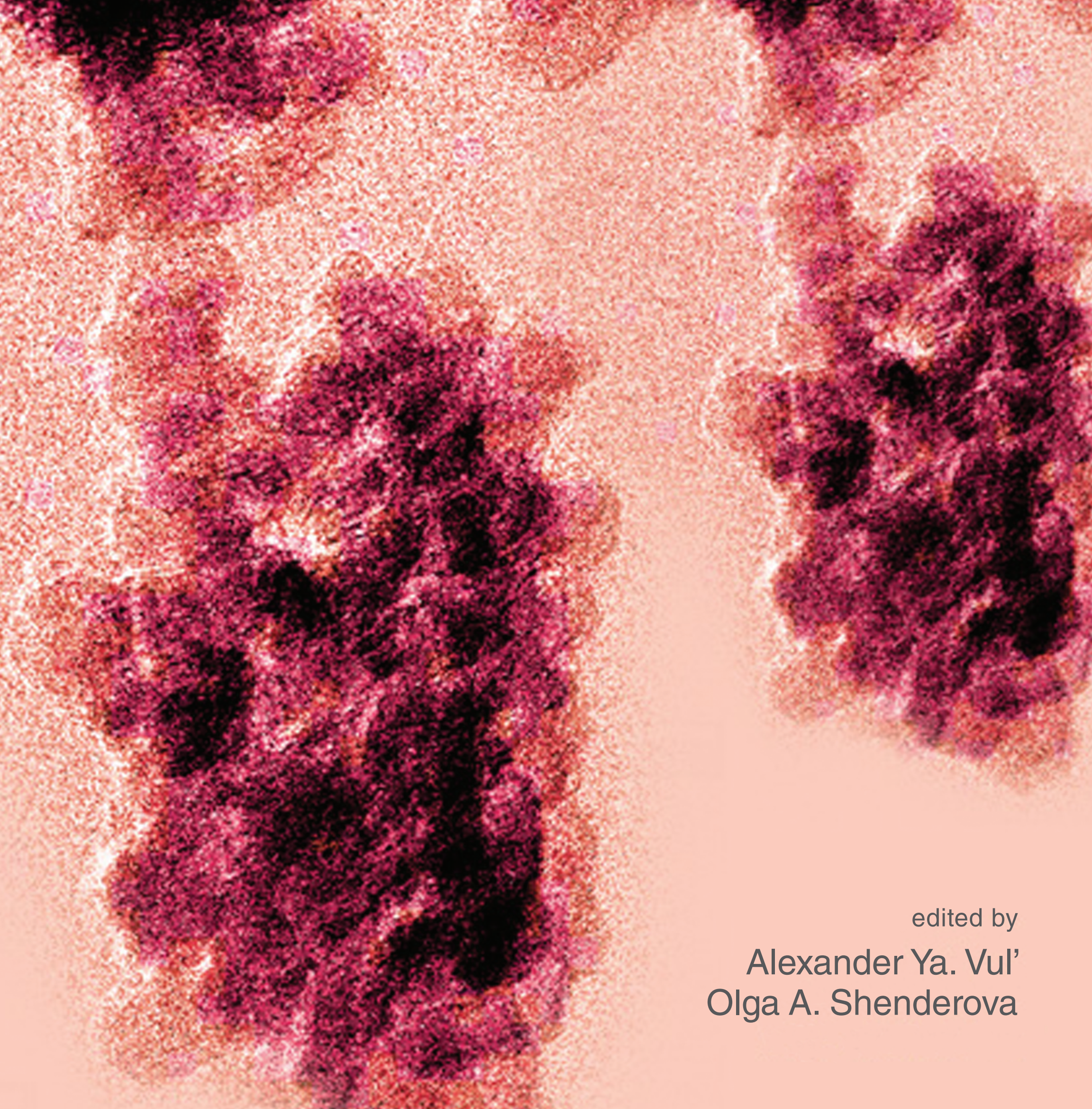

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Detonation Nanodiamonds: Science and Applications

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Preface

Diamond has been well known since time immemorial, and applications of this material, truly unique in its beauty, hardness, and chemical stability, keep expanding as years go by. For hundreds of years mankind has used natural diamonds, but it was only from the mid-1950s that industrial production of diamond on a commercial scale in reactors capable of maintaining the required high pressures, of tens of thousands of atmospheres, and temperatures of about 1,500 degrees Kelvin was announced to the world.

Annual production of such artificial diamonds ranging in size from a few hundred to a few microns, the so-called micropowders, has presently reached a level of hundreds of thousands of carats per year.

Presently, when most technologies are moving with confidence from the microscale into the nanometer-scale world, demand has arisen for diamonds of the corresponding size. Such nanodiamonds were first synthesized in the Soviet Union in the 1960s and their industrial production initiated in the late 1980s. The starting raw material for nanodiamond synthesis was carbon, present originally in explosives, and the high pressure and temperature needed for formation of the diamond structure from carbon atoms were reached as a result of the explosion itself. The short duration of the explosion accounted for the small size of the diamond crystallites, which measured a few billionths of a meter only.

As is now obvious, work conducted on the explosive method of synthesis was not made public for a period of time. As a consequence, this method of preparing nanodiamonds from the carbon of explosives was discovered over and over again independently by different research groups.

From the publication of the pioneering works on the so-called detonation nanodiamonds made in Russia and the United States in 1988, scientists have passed a long way indeed.

The first studies were naturally devoted to the investigation of the synthesis process and were aimed at increasing the fraction of the carbon atoms contained within the explosive eventually incorporated into the diamond lattice of the final product of the synthesis. Possibly, the most challenging problem in the process turned out to be the development of the technology for isolating the diamond crystallites from the final product, that is, the detonation carbon formed during the explosion. Detonation carbon is actually a mixture of nanodiamonds; particles of amorphous, graphite-like carbon; and impurities entering the material from the starting explosive and the reactor walls.

This work was paralleled by an investigation of the processes involved in the nanodiamond-graphite structural phase transition. The high temperature persisting during the unavoidable drop of pressure after the explosion brought about reverse transformation of a part of the formed nanodiamonds into graphite, thus lowering the efficiency of the synthesis process. It was, however, found that under certain conditions this structural phase transition passes through an intermediate stage in which onion-like carbon or multilayer fullerenes form. Moreover, if acted upon by an electron beam, the buckyonions themselves can reconvert back into nanodiamonds. This has revealed an intimate relationship between the fullerenes discovered in 1980s and nanodiamonds.

The emerging possibility of studying structural transformations on the nanoscale was naturally attractive to scientists. No less intriguing was finding nanodiamonds in meteorites. This finding alone could have been sufficient to account for the interest in nanodiamonds revealed in basic sciences, but it is the industrial application of nanodiamonds that is behind the attention focused presently on the investigation of their properties.

Studies conducted during recent years showed that nanodiamonds, new nanosized building blocks, can be used to advantage in devising nanocomposite materials, nanoelectronics components, selective adsorbents, and catalysts.

Application of nanodiamonds improves considerably the quality of microabrasive and polishing compositions, lubricating oils, abrasive instruments, polymer compositions, rubbers, and magnetic recording systems and offers the possibility of growing diamond films on various substrates.

One of the most attractive applications of nanodiamonds turned out to be their use in biology and medicine as biomarkers and for targeted drug delivery.

A significant factor that has apparently played a major role in stimulating interest in detonation nanodiamonds is that among the new carbon nanostructures discovered at the turn of the century—various types of fullerenes and nanotubes—detonation nanodiamonds were one of the first to be produced on an industrial scale and, thus, are commercially available for use in nanotechnologies.

In our opinion, progress in methods of synthesis of detonation nanodiamonds and clear insight into the broad scope of their applications have approached at the beginning of this century the stage where detonation nanodiamonds are considered one of the most attractive carbon-based materials for nanotechnologies. By this time, reports on nanodiamonds produced in detonation synthesis began to appear at increasing frequency at international "diamond devoted" conferences. In the period of 2003–2008, the first specialized conferences were held and reviews and monographs dealing with this material appeared.

Studies conducted in recent years in Russia, the United States, Japan, China, and a number of European countries have produced a wealth of comprehensive information on the specific features of the structure of nanodiamond particles. Truly unique possibilities have opened up as a result of chemical modification of their surface, leading to considerable promise for their use in numerous applications. The results of these studies are summarized in this monograph. The authors of the chapters of the monograph are world-renowned experts who have published a number of review papers in this area.

The monograph addresses successively the specific features of the production technology and the effect of the technological parameters on the structure and physicochemical properties of nanodiamonds, assesses the possibilities inherent in purposefully directed chemical modification of the surface and methods employed in structural modification of nanodiamonds to produce nanographite, discusses various approaches used in the investigation of nanodiamonds as a carbon nanostructure, and describes and critically analyzes the potential promised by the use of nanodiamonds in various areas of technology and medicine.

There are two significant features that distinguish the present monograph. First, rather than being just a collection of individual reviews, it is a book written with a common theme. Second, the monograph is published in both Russian and English, an approach that, in our opinion, will be a step forward in developing a common terminology and a common view of many problems, both already solved and those still remaining open, that bear on detonation nanodiamonds.

The monograph addresses a broad audience of readers interested in nanotechnologies, and we sincerely hope that it will be found useful both by specialists in the field and senior students who are still looking for challenging problems to direct their efforts to.

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